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MONTGOMERY WATSON

11107 Aurora Avenue
Des Moines, Iowa 50322

Tel: 515 253 0830
Fax: 515 253 0952

Date: April 30, 1996

To: Elizabeth Koesterer

cc: Gary McConnell, Sauer-Sundstrand Company
Scott Moyer, Sundstrand Corporation

From: Jeff Coon / Lisa Larson

Re: Sauer-Sundstrand CMS

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General Remarks:

Four copies of the Sauer-Sundstrand CMS Report are enclosed. Please review the report along with Don Lininger. If you have questions or comments, please contact Jeff Coon at (515)253-0830.

Sincerely,

Lisa Larson

Lisa Larson
Project Engineer

Sauer-Sundstrand Company
Ames, Iowa

Corrective Measures Study Report

April 1996

MONTGOMERY WATSON

CORRECTIVE MEASURES STUDY REPORT

FOR

SAUER-SUNDSTRAND FACILITY
AMES, IOWA

Prepared for

SAUER-SUNDSTRAND COMPANY

Project No. 8907.0340

April 1996

Prepared by

Montgomery Watson
11107 Aurora Avenue
Des Moines, Iowa 50322
515-253-0830

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly Registered Professional Engineer under the laws of the State of Iowa.

Signature: Jeff L Coon

Name: Jeffrey L. Coon, P.E.

Date: 4/30/96 **Reg. No.:** 11975

My registration expires December 31, 1996.

JEFFREY L. COON
REGISTERED
11975
IOWA
PROFESSIONAL ENGINEER

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INTRODUCTION

OBJECTIVE

This Corrective Measures Study (CMS) Report was prepared by Montgomery Watson on behalf of the Sauer-Sundstrand Company (Sauer-Sundstrand). The content generally follows the Scope of Work for CMS Activities (Scope of Work) as outlined in the March 14, 1996 letter to the United States Environmental Protection Agency (USEPA) which received subsequent approval on March 21, 1996. The purpose of the CMS Report is to identify and evaluate potential remedial alternatives for the releases that have been identified at the Sauer-Sundstrand Ames, Iowa facility (facility).

Specific objectives of the CMS Report are to:

- Present an abbreviated risk assessment regarding the presence of constituents in groundwater.
- Set CMS objectives in light of risk assessment considerations.
- Identify corrective action alternatives.
- Evaluate the corrective action alternatives, individually and comparatively, based upon criteria established in the Scope of Work.
- Recommend the corrective measure or measures to be undertaken at the facility.

SITE BACKGROUND

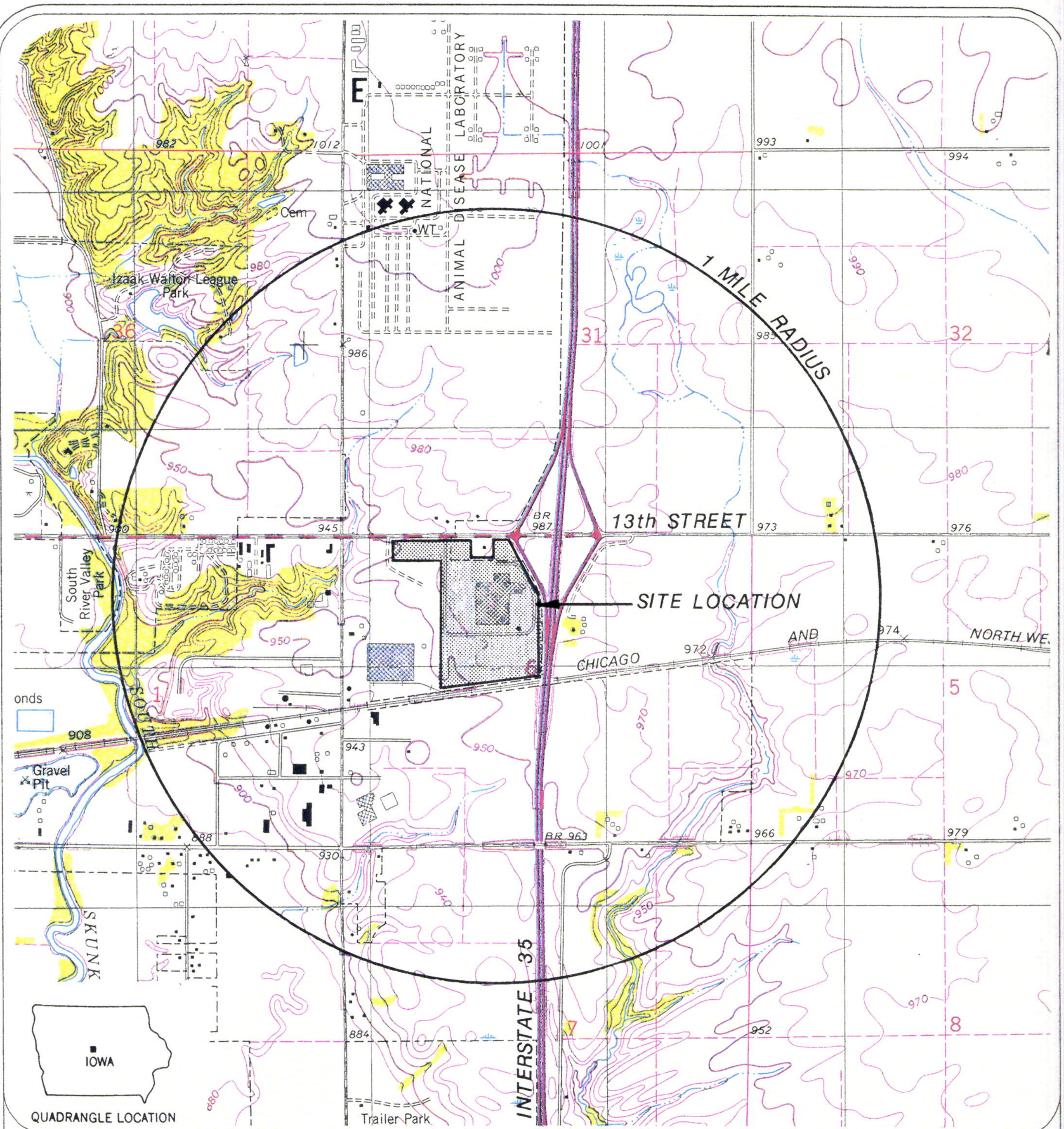
Site Location

The Sauer-Sundstrand site (site) is located in Ames, Iowa, within the Northeast 1/4 of the Northwest 1/4 of Section 6, Township 83 North, Range 23 West, Story County, Iowa (Figure 1-1). The site is bounded on the north by 13th Street and on the east by Interstate 35. A small portion of the property located on the south side of 13th Street is owned by Doolittle Oil Company, Inc. The Chicago and Northwestern (CNW) Railroad tracks form the southern site boundary. A 3M Corporation plant is located west of the site. The South Skunk River, located approximately one mile west of the site, flows generally toward the south.

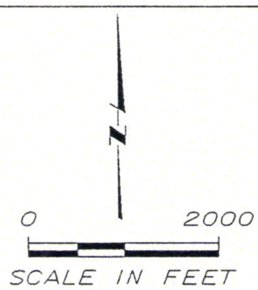
Land use near the site consists of general industrial use to the west and south. On the northern side of 13th Street, the land is zoned for general commercial use. Land further north is zoned for agricultural use. The land east of Interstate 35 is primarily used for agricultural purposes, and most of this eastern area is located outside the corporate limits of the City of Ames. Residential land use located within one mile of the site is limited.

Facility Operations

The Sauer-Sundstrand facility operates as a manufacturer of hydrostatic transmission power systems for use primarily in farm machinery and construction equipment. The facility began



MAP SOURCE: U.S.G.S. 7.5 MINUTE SERIES TOPOGRAPHIC MAP
AMES EAST QUADRANGLE



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SAUER–SUNDSTRAND FACILITY
AMES, IOWA

SITE VICINITY MAP

FIGURE 1–1

BDR

operations in 1972 under the ownership of Sundstrand Corporation. On January 1, 1987, Sundstrand entered into a joint venture with Sauer Getriebe AG (Sauer) and began operation as the Sundstrand-Sauer Company. When Sundstrand sold its interest in the joint venture to Sauer on March 31, 1989, ownership of the real estate was transferred to Susa Holding of Story County. Operations of the Sundstrand-Sauer Company continued until December 31, 1989 when an independent entity, Sauer-Sundstrand Company, was established. Sauer-Sundstrand has operated the facility since January 1, 1990.

RCRA History

On March 29, 1991, an Administrative Order on Consent (Consent Order) Docket Number VII-91-H-0009 was entered into between the USEPA, Sundstrand Corporation, Sauer-Sundstrand Company and Susa Holding Inc. (Respondents). A RCRA Facility Investigation (RFI) was conducted pursuant to Section VI.B.6 of the Consent Order. The RFI was conducted in accordance with a set of project plans prepared by Harding Lawson Associates (HLA) including a Data Collection Quality Assurance Plan (DCQAP), as modified by the USEPA Notice of Approval with Modifications Letter dated August 3, 1993; a Health and Safety Plan (HSP); a Project Management Plan (PMP); a Data Management Plan (DMP); and a Community Relations Plan (CRP). The objective of the RFI was to assess impacts to soil and groundwater from the release, or potential release, of hazardous constituents from Solid Waste Management Units (SWMUs) at the facility.

Investigation activities were implemented at the site from September through October 1994 by HLA. Following the investigation, an RFI Report was prepared by HLA and submitted to the EPA on June 9, 1995 in accordance with the Consent Order. The RFI Report defined the source, degree and extent of constituents in the groundwater; and identified actual or potential receptors in the source area. On January 29, 1996, USEPA comments on the June 1995 RFI Report were received by HLA. A letter of Response to Technical Comments was submitted to the USEPA on March 18, 1996 to address these comments.

In March 1996, Montgomery Watson was retained to initiate the CMS phase of RCRA activities for the Sauer-Sundstrand site. CMS activities at the site are being conducted by Sauer-Sundstrand voluntarily in an effort to proactively address identified constituents in the groundwater at the site.

Site Hydrogeology

As presented in the RFI Report, the subsurface geology at the site consists mainly of dense, gray, clay-rich glacial till interbedded with numerous and discontinuous sand units. Two main water-bearing zones appear to exist in the unconsolidated sediments of the site. A shallow water-bearing zone occurs from the water table (generally encountered at approximately 4 to 6 feet below ground surface) to a depth of approximately 15 to 20 feet below ground surface where the geology changes from soft, sandy clay, containing numerous sand pockets of limited horizontal and vertical extent to a hard, gray, silty clay.

Underlying the shallow water-bearing zone is the intermediate water-bearing zone which consists of numerous sand lenses interspersed throughout a dense, gray, clay-rich glacial till.

Sand layers in the till have been encountered at depths ranging from approximately 15 to 50 feet below ground surface. The intermediate groundwater sand units are generally thicker than those encountered in the shallow water bearing zone; however, they too appear discontinuous. Based upon information presented in the RFI Report, it was concluded that the lower conductivity of the intermediate zone restricts vertical flow of water from the shallow sand units to those in the intermediate zone.

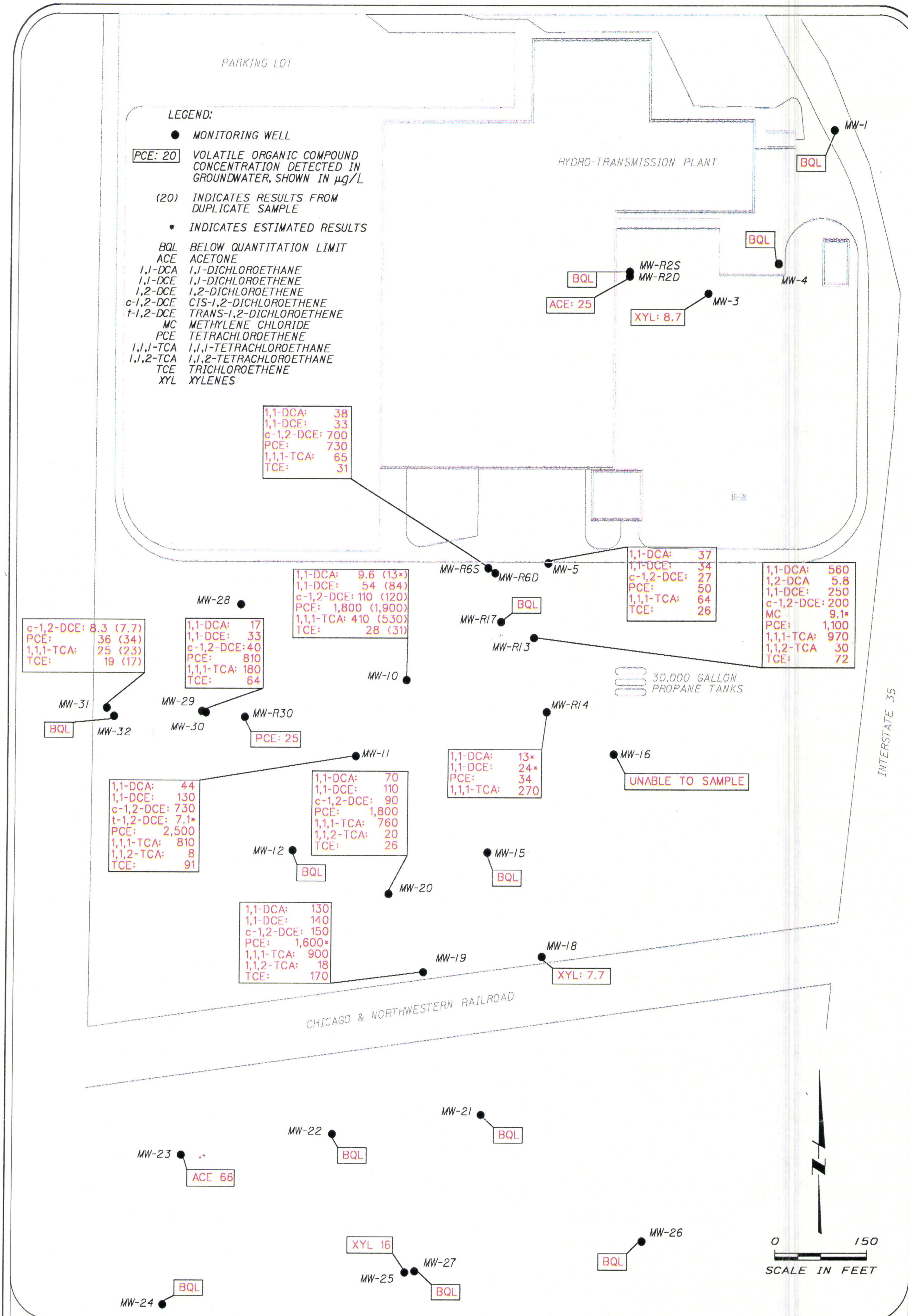
Results of previous investigations indicated the horizontal direction of groundwater flow in the shallow water-bearing zone is toward the southwest. Groundwater in the intermediate water-bearing zone flows toward the south. As presented in RFI Report, detections of constituents in groundwater were generally limited to monitoring locations at which sandy materials were encountered within the shallow water-bearing zone. Low concentrations of constituents observed in the intermediate zone were attributed to cross-contamination associated with past site investigations.

Extent of Groundwater Impacts

During the RFI, evidence of volatile organic compounds (VOCs) in groundwater were observed at monitoring well locations in the central and southwestern portions of the site (Figure 1-2). The highest concentrations of total VOCs in groundwater were detected at monitoring well locations MW-11, MW-R13 and MW-19. VOC concentrations in groundwater samples collected from downgradient monitoring well locations MW-21, MW-22 and MW-23 were generally below method detection limits. An isolated detection of acetone was observed in MW-23 at a concentration of 66 µg/L (Figure 1-2).

Historic groundwater monitoring data suggests that the VOC plume is migrating in the direction of shallow groundwater flow toward the southwest. As presented in the RFI Report, results from a Pre-RFI investigation conducted in January and February 1990 indicated that the highest VOC concentrations were detected at MW-R13 (Figure 1-3). When results of the 1990 sampling event are compared with those resulting from the RFI (September and October 1994), the location of maximum VOC concentrations apparently shifted downgradient from the vicinity of MW-R13 to MW-11, located approximately 350 feet to the southwest.

Further comparison of the 1990 and 1994 sampling events indicates that VOC concentrations have generally decreased in the upgradient portion of the plume. Decreases were particularly notable in the vicinity of MW-10, MW-11, MW-R13, MW-R14 and MW-R17 (Figures 1-2 and 1-3). Concurrently, increases in constituent concentrations were noted at several downgradient monitoring locations including MW-28, MW-31, MW-18 and MW-19 (Figures 1-2 and 1-3). The observed shift in the center of mass of the plume is consistent with interpretations of groundwater flow presented in the RFI Report. Information presented in the RFI Report, indicates the VOC constituents in the groundwater have not migrated beyond the Sauer-Sundstrand property boundary (Figure 1-3).



NOTE: DATA TAKEN FROM HARDING LAWSON ASSOCIATES JUNE 1995 REPORT.

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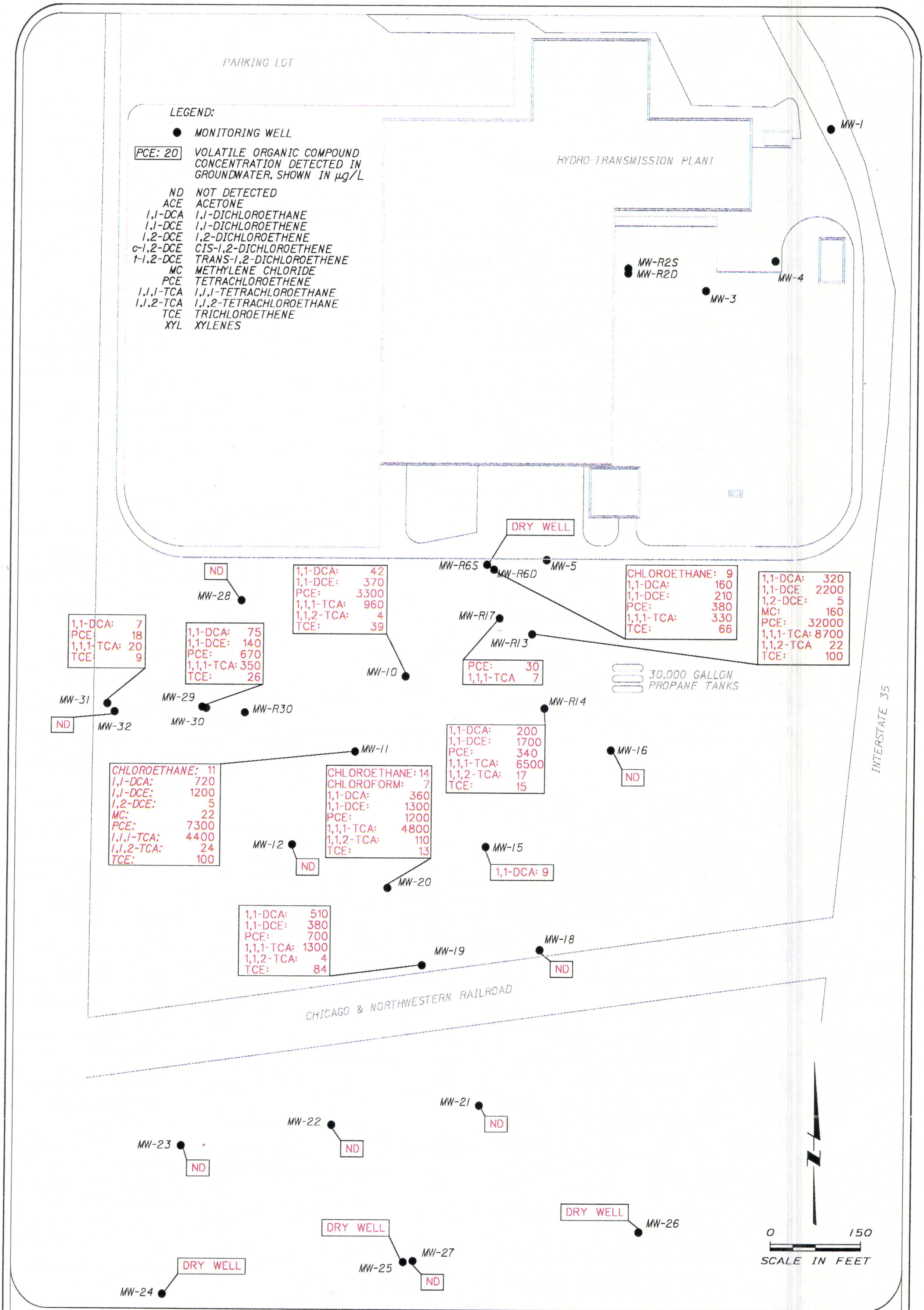
AMES, IOWA

GROUNDWATER ANALYTICAL RESULTS SEPT.-OCT. 1994

FIGURE 1-2



NOTE: DATA TAKEN FROM HARDING LAWSON ASSOCIATES JUNE 1995 REPORT.

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AMES, IOWA

AREAL EXTENT OF VOCs IN GROUNDWATER JAN.–FEB. 1990

FIGURE 1–3

SECTION 2

SECTION 2

RISK ASSESSMENT AND CMS OBJECTIVES

This section identifies the CMS objectives for the Sauer-Sundstrand site. A risk assessment is initially presented to provide a basis for evaluating the potential human health risk associated with constituents in the groundwater at the site.

RISK ASSESSMENT

This risk assessment (RA) is presented to provide information regarding the potential risk posed by VOCs in the groundwater at the Sauer-Sundstrand site to human health and the environment. The RA is an abbreviated version and is focused only on the potential human health risk associated with drinking groundwater emanating from the site. The RA is based on the sampling results from the RFI and the overall approach follows the guidance provided in Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual (RAGS). This RA uses very conservative assumptions and, therefore, probably overestimates the risks significantly. For example, while the RA focuses on ingestion of groundwater as the only plausible potential exposure pathway, there is no current or reasonably expected future use of the shallow groundwater for drinking water purpose.

As a condensed RA, the format follows the organization of RAGS in an expedited fashion. The constituents of concern (COCs) are identified, and the potentially exposed population and exposure pathways are developed. The toxicity assessment presents the quantitative toxicity values for the COCs, although discussions of the toxicological effects of the COCs are not included in this document. Calculated risk values and calculations are subsequently presented with a discussion of the noncarcinogenic and carcinogenic risks.

Constituents of Concern

The COCs at the Sauer-Sundstrand site include VOCs detected in monitoring wells at concentrations greater than the established regulatory Maximum Contaminant Levels (MCLs) as identified in the RFI Report.

A list of COCs, their frequency of detection, and the concentration ranges of the COCs detected in these areas is presented in Table 2-1.

Exposure Assessment

Potential exposure to COCs at the Sauer-Sundstrand site was considered for ingestion by drinking groundwater. This results in a very conservative RA. There are no actual exposures, of any kind to any person, of compounds present in on-site groundwater. For purposes of this RA, two scenarios were evaluated for potential exposure: 1) a drinking water well is assumed to be installed in a location exhibiting the highest concentrations present at the site, or 2) a drinking water well is installed at the nearest off-site downgradient location. For Scenario #1, the exposure assessment utilizes the highest concentration of a COC detected in any monitoring wells at the site, regardless of location. In this manner, risks associated with drinking water from

TABLE 2-1

CONSTITUENT DISTRIBUTIONS
SAUER-SUNDSTRAND FACILITY - AMES, IOWA

Constituent	Frequency of Detection[a]	Concentration Range of Detections (µg/L)	Carcinogenic Classification[b]
1,1-Dichloroethene	10/33	33 - 250	C
1,1-Dichloroethane	10/33	9.6 - 560	-
cis-1,2-Dichloroethene	11/33	7.7 - 730	D
1,1,1-Trichloroethane	12/33	23 - 970	D
Trichloroethene	11/33	17 - 170	UR
1,1,2-Trichloroethane	4/33	8 - 30	C
Tetrachloroethene	14/33	6.2 - 2,500	UR

[a] Indicates detections/number of samples collected.

[b] Carcinogenic classifications as of March 28, 1996 per EPA Region 3 Risk Based Concentration Tables (10-20-95).

\- Indicates no information available.

C Indicates possible human carcinogen. Limited evidence from animal studies and inadequate or no data in humans.

D Indicates not classifiable. Inadequate or no human and animal evidence of carcinogenicity.

UR Indicates under review.

this hypothetical well would be most conservative. For Scenario #2, exposure point concentrations were taken from VOC concentrations detected at MW-19, located at the southern property boundary of the Sauer-Sundstrand site. According to the RFI Report, MW-19 is generally positioned downgradient of the facility in the uppermost aquifer. Though Scenario #2 is unlikely, VOC concentrations detected in this well would conservatively represent concentrations detected at the nearest off-site location.

For both of the exposure assumptions, it is assumed that no attenuation or dilution of constituent concentrations would occur in groundwater during constituent migration into the potential drinking water well.

Pathway-specific chronic daily intakes (CDIs) are calculated using the exposure point concentrations presented in Tables 2-2 and 2-3 and are expressed as the amount of a constituent an individual may be exposed to per unit body weight per day (mg/kg-day). Standard formulas for determining CDIs are presented in RAGS. A conservative assumption underlying the CDI calculations is that constituent concentrations remain constant over the entire period of exposure.

The equation used for determining the CDI for ingestion of constituents in water is (RAGS, 1989):

$$\text{CDI} = \frac{\text{CW x IR x EF x ED}}{\text{BW x AT}}$$

Where:

CDI	=	Chronic Daily Intake (mg/kg-day)
CW	=	Chemical Concentration in Water (mg/L)
IR	=	Ingestion Rate (L/day)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (days)

Assumptions regarding this exposure pathway include:

- Ingestion rate is 2 liters per day.
- Exposure frequency is 350 days per year (two-week period for vacations, etc.).
- Exposure duration is equal to 30 years (people will be drinking the water for 30 years).
- Body weight is equal to a 70 kg adult.
- The averaging time is equal to 365 days per year for 30 years for noncarcinogenic compounds and 365 days per year for 70 years for carcinogenic compounds.

For noncarcinogenic compounds, an example calculation for the concentration of 1,1-dichloroethane found at MW-19 is:

$$\text{CDI} = (\text{mg/kg - day}) = \frac{(0.13 \text{ mg/L})(2\text{L/day})(350 \text{ day/yr})(30 \text{ yrs})}{(70 \text{ kg})(365 \text{ days/yr x } 30 \text{ yrs})} = 3.56\text{E - 03 mg/kg - day}$$

TABLE 2-2

NONCARCINOGENIC RISK ESTIMATES
SAUER-SUNDSTRAND FACILITY - AMES, IOWA

Noncarcinogenic Risk Estimates	Constituents of Concern	Exposure Point Concentration (mg/L)	Chronic Daily Intake (mg/kg-day)	Reference Dose (mg/kg-day)	Hazard Quotient	Hazard Index
Scenario #1 - Highest Site Concentrations	1,1-Dichloroethane	0.56	1.53E-02	1.00E-01	1.53E-01	
	1,1-Dichloroethene	0.25	6.85E-03	9.00E-03	7.61E-01	
	cis-1,2-Dichloroethene	0.73	2.00E-02	1.00E-02	2.00E+00	
	Tetrachloroethene	2.5	6.85E-02	1.00E-02	6.85E+00	
	1,1,1-Trichloroethane	0.97	2.66E-02	3.50E-02	7.59E-01	
	1,1,2-Trichloroethane	0.03	8.22E-04	4.00E-03	2.05E-01	
	Trichloroethene	0.17	4.66E-03	6.00E-03	7.76E-01	
						1.15E+01
Scenario #2 - MW-19 Data	1,1-Dichloroethane	0.13	3.56E-03	1.00E-01	3.56E-02	
	1,1-Dichloroethene	0.14	3.84E-03	9.00E-03	4.26E-01	
	cis-1,2-Dichloroethene	0.15	4.11E-03	1.00E-02	4.11E-01	
	Tetrachloroethene	1.6	4.38E-02	1.00E-02	4.38E+00	
	1,1,1-Trichloroethane	0.9	2.47E-02	3.50E-02	7.05E-01	
	1,1,2-Trichloroethane	0.018	4.93E-04	4.00E-03	1.23E-01	
	Trichloroethene	0.17	4.66E-03	6.00E-03	7.76E-01	
						6.86E+00

TABLE 2-3

CARCINOGENIC RISK ESTIMATES
SAUER-SUNDSTRAND FACILITY - AMES, IOWA

Carcinogenic Risk Estimates	Constituents of Concern	Exposure Point Concentration (mg/L)	Chronic Daily Intake (mg/kg-day)	Slope Factor	Cancer Risk Level	Estimated Total Risk
Scenario #1 - Highest Site Concentrations	Trichloroethene	0.17	2.00E-03	3.00E-02	5.99E-05	
	1,1-Dichloroethene	0.25	2.94E-03	9.00E-03	3.26E-01	
	Tetrachloroethene	2.5	2.94E-02	1.00E-02	2.94E+00	
	1,1,2-Trichloroethane	0.03	3.52E-04	4.00E-03	8.81E-02	3.35E+00
Scenario #2 - MW-19 Data	Trichloroethene	0.17	2.00E-03	3.00E-02	5.99E-05	
	1,1-Dichloroethene	0.14	1.64E-03	9.00E-03	1.83E-01	
	Tetrachloroethene	1.6	1.88E-02	1.00E-02	1.88E+00	
	1,1,2-Trichloroethane	0.018	2.11E-04	4.00E-03	5.28E-02	2.11E+00

Notes:

Slope factors for trichloroethene and tetrachloroethene are currently under evaluation.

Slope factors obtained from EPA Region 3 Risk Based Concentration Tables (10-29-95).

For carcinogenic compounds, an example calculation for trichloroethene (TCE) found at MW-19 is:

$$\mathrm{CDI} = (\mathrm{mg/kg\text{-}day}) = \frac{(0.17\ \mathrm{mg/L})(2\mathrm{L/day})(350\ \mathrm{day/yr})(30\ \mathrm{yrs})}{(70\ \mathrm{kg})(365\ \mathrm{days/yr} \times 70\ \mathrm{yrs})} = 2.00\mathrm{E}-03\ \mathrm{mg/kg\text{-}day}$$

The CDIs for all COCs are presented in Tables 2-2 and 2-3.

The CDI calculations rely on many industry standard exposure values that are more likely to overestimate risks at the site. Uncertainties from various sources may be compounded in the exposure assessment, making the estimates of risk at the site very conservative. The actual chemical exposures would be much lower than presented in this RA.

Toxicity Assessment

Evaluation of the toxic potential of a chemical involves the examination of available data that relate observed toxic effects to doses. Generally, there are two categories of information that are considered in this part of a quantitative risk assessment:

- Information on the potential acute or chronic noncancer effects of chemicals.
- Information on the potential for chemicals to initiate or promote cancers.

A wide variety of factors must be considered in using health effects data in qualitative or quantitative assessments. As discussed in the following subsections, there may be a variety of relationships between dose and effects. Also, the fact that some chemicals display thresholds (i.e., there are doses below which the chemical does not cause an effect) must be considered.

Noncarcinogenic Effects. Noncarcinogenic (acute or chronic systemic) effects are considered to have a finite dose (threshold), below which adverse effects will not occur. For many noncarcinogenic effects, protective mechanisms must be overcome before the effect is manifested. Toxicity studies for noncarcinogenic effects focus on identifying where this threshold occurs. The threshold can be related to a reference dose (RfD). A chronic RfD is an estimate of a daily exposure level for which people, including sensitive individuals, do not have an appreciable risk of suffering significant adverse health effects. Exposure doses above an RfD could possibly cause health effects.

Carcinogenic Effects. Studies of carcinogenicity tend to focus on identifying the slope of the linear portion of a curve of dose versus response. A plausible upper-bound value of the slope is called the cancer slope factor (CSF) or cancer potency factor (CPF). The product of the CSF and the exposure dose is an estimate of the excess risk of developing cancer due to chemical exposures. In accordance with current scientific policy concerning carcinogens, it is assumed that any dose, no matter how small, has some associated response. This is called a nonthreshold effect. In this assessment, the nonthreshold effect was applied to all probable carcinogens.

A distinction is made between carcinogenic and noncarcinogenic effects. For potential carcinogens, the current regulatory guidelines use an extremely conservative approach in which it is assumed that any level of exposure to a carcinogen could hypothetically cause cancer. This is contrary to the traditional toxicological approach to toxic chemicals, in which finite thresholds are identified, below which toxic effects are not expected to occur. This traditional approach still is applied to noncarcinogenic chemicals.

In general, CSFs and RfDs are taken from IRIS (1993) or, in the absence of IRIS data, the USEPA Health Effects Assessment Summary Tables (HEAST) (USEPA, 1995) and USEPA Region 3 Risk Based Concentration Tables (USEPA, 1995).

Risk Characterization

Toxicity values are combined with the CDIs to develop quantitative health risk estimates for constituents at the Sauer-Sundstrand site.

<u>Noncarcinogenic Risk Estimates</u>. Estimates of chemical-specific exposure levels (CDIs) are compared to established chemical-specific toxicity values (RfDs) to evaluate the potential for noncarcinogenic health effects to occur at the site. The hazard quotient (HQ) is the ratio of the estimated exposure dose to toxicity and is calculated as follows:

$$\text{Hazard Quotient} = \frac{\text{CDI}}{\text{RfD}}$$

Where:

CDI = Chronic Daily Intake (mg/kg-day)
RfD = Reference Dose (mg/kg-day)

An HQ greater than 1 indicates there is potential for noncarcinogenic adverse health effects to exist. For an HQ less than 1, it is assumed there is a level of exposure below which it is unlikely that adverse health effects will appear in chronically exposed populations. The sum of HQs for the COCs associated with an exposed population is termed the hazard index (HI). If the HI is less than 1, then no chronic health effects are expected to occur. If the HI is greater than 1, then adverse health effects are possible. Due to the margin of safety built into the RfD value, exceedance of an HI of 1 has no immediate meaning with regard to specific health effects, the frequency of effects or the magnitude of effects.

The HQs and HIs for groundwater ingestion under the two exposure assumptions are presented in Table 2-2. Considering all groundwater sampling data, the HI resulting from VOC exposure is greater than 1 at 6.86. Using the MW-19 data, the HI is also greater than 1 at 11.5. The COCs contributing most to both exposure pathways are tetrachloroethene, (PCE), 1,1,1-trichloroethane (TCA) and cis-1,2-dichloroethene (DCE) (Table 2-2).

<u>Carcinogenic Risk Estimates</u>. To evaluate cancer risks, chemical-specific exposures (CDIs) are multiplied by the CSFs to determine the excess lifetime cancer risk associated with lifetime exposure, at specified daily doses, to COCs detected at the site. The risk estimate is considered an incremental upper-bound estimate, where incremental risks in the range of 1×10^{-6} to 1×10^{-4} are generally characterized as acceptable by the EPA. The one in one million (1×10^{-6}) risk level is a theoretical prediction that no more than one person out of a million lifetimes would contract

cancer due to environmental exposure. These small risk levels may be of concern only if the exposed population includes many millions of people.

The cancer risk levels for groundwater ingestion at the Sauer-Sundstrand site are presented in Table 2-3. Potential carcinogens at the site include trichloroethene, 1,1-dichloroethene, tetrachloroethene and 1,1,2-trichloroethane. Using slope factors obtained from EPA Region 3's Risk Based Concentration Tables, a cancer risk level per constituent and total risk level were calculated for both Scenario #1 (highest site concentrations) and Scenario #2 (MW-19 data). As presented in Table 2-3, the total cancer risk levels calculated for these exposure pathway scenarios (3.35 and 2.11, respectively), exceeded the range of risk values generally characterized as acceptable by the EPA.

Summary of Risk Assessment

Noncancer and cancer risks were evaluated for the Sauer-Sundstrand site based on exposure to COCs through groundwater ingestion. This RA considered COCs to be VOCs detected above the MCLs in monitoring wells at the site. Exposure scenarios were developed for drinking groundwater from the area of the site exhibiting the highest constituent concentrations, and drinking water from MW-19 located at the southern property boundary. The RA used industry standard exposure equations and assumptions (RAGS, 1989). For both drinking water exposure scenarios, noncancer risks were greater than health-based benchmark levels (HI greater than 1). The noncancer risk levels of 11.5 for Scenario #1 (i.e., highest constituent levels) and 6.86 for Scenario #2 (MW-19 data) suggest that adverse health effects are possible if groundwater from the site is consumed at a frequency and quantity assumed by the exposure assessment.

The total cancer risk levels associated with Scenario #1 (3.35) and Scenario #2 (2.11) exceed the acceptable level of risk designated by the EPA (cancer risk of 1×10^{-4}).

It should be noted that risks associated with exposure pathways are only meaningful if the pathways are completed. The potential for future development of shallow groundwater resources in the vicinity of the Sauer-Sundstrand site is highly remote due to aquifer yields resulting from the presence of clay soils. Yields from the shallow groundwater would be insufficient to deliver a potable water supply to an individual or the City of Ames. Moreover, off-site groundwater has not been demonstrated to have been impacted. Sauer-Sundstrand can control (i.e., eliminate) use of on-site groundwater for drinking. The data presented in this RA clearly represent upper-bound estimates for potential risks at the site.

CMS OBJECTIVES

Based on the results of the RA and the nature and extent of constituents in the groundwater presented in the RFI Report, the overall objective of CMS activities at the Sauer-Sundstrand site is to protect human health and the environment and mitigate off-site migration of groundwater constituents. Specific CMS objectives are as follows:

- Mitigate off-site migration of groundwater containing concentrations of VOCs above MCLs.

- If an MCL has not been established for a VOC, mitigate off-site migration of groundwater containing concentrations of VOCs that represent an unacceptable human health or environmental risk.

Meeting these individual objectives will ensure that the overall objective of CMS activities is achieved at the Sauer-Sundstrand site.

SECTION 3

SECTION 3

EVALUATION AND COST ANALYSIS OF INDIVIDUAL ALTERNATIVES

The purpose of this section is to provide an engineering evaluation and cost analysis of the CMS alternatives proposed for the Sauer-Sundstrand site. The alternatives evaluated consist of those which were presented in the approved CMS scope of work following an initial screening process. This section includes an overview of the evaluation criteria used and summarizes evaluation of the alternatives in terms of their effectiveness, implementability and cost.

OVERVIEW OF EVALUATION CRITERIA

Effectiveness

The effectiveness of each alternative is evaluated with regard to protectiveness of human health and the environment, safety considerations, and the overall ability to meet the CMS objectives. Criteria for evaluating the effectiveness of alternatives are presented below.

- Ability to meet CMS objectives established for the groundwater plume.
- Overall protection of human health and the environment measured by the ability of the alternative to maintain or achieve an acceptable level of residual risk.
- Safety and potential human and environmental exposure considerations associated with implementation of the alternatives.
- Time required to implement the alternative and to recognize beneficial results.
- Ability of the alternative to perform its intended function and reduce residual risk.
- Reliability and proven performance of the alternative.

Implementability

Implementability focuses on technical and administrative feasibility of implementing the alternatives. Criteria used for evaluating implementability includes the following:

- Constructability as determined by such items as the relative degree of difficulty to construct and operate, availability of goods and services, and availability of equipment and support required to implement the alternative.
- Operation and maintenance requirements, including frequency and complexity of required maintenance and future flexibility of the alternative.
- Institutional considerations, including applicable regulations.

Cost

An independent cost analysis for each alternative includes projected capital costs, operation and maintenance (O&M) costs, and present annualized costs. These cost estimates are based on a variety of information including estimates from suppliers, generic unit costs, vendor information, conventional cost estimating guides, and prior experience. The cost estimates shown have been prepared for comparison only and are derived from information available at the time of the estimate preparation. The actual costs of the project will depend on the true labor and material costs, actual site conditions, competitive market conditions, final project scope, implementation schedule, and other variable factors. Uncertainties could significantly impact the costs presented in this report. Criteria used for evaluating costs are presented below:

- Capital costs include those expenditures required to implement the remedial action. Both direct and indirect costs are considered in the development of capital cost estimates. Direct costs include construction costs or expenditures for equipment, labor, and materials required to implement the alternative. Indirect costs include those associated with engineering, permitting (as required), construction management and other services necessary to carry out the alternative.

- The annual O&M costs, which include operation labor, maintenance materials and labor, monitoring and laboratory costs, and energy and purchased services, will also be determined.

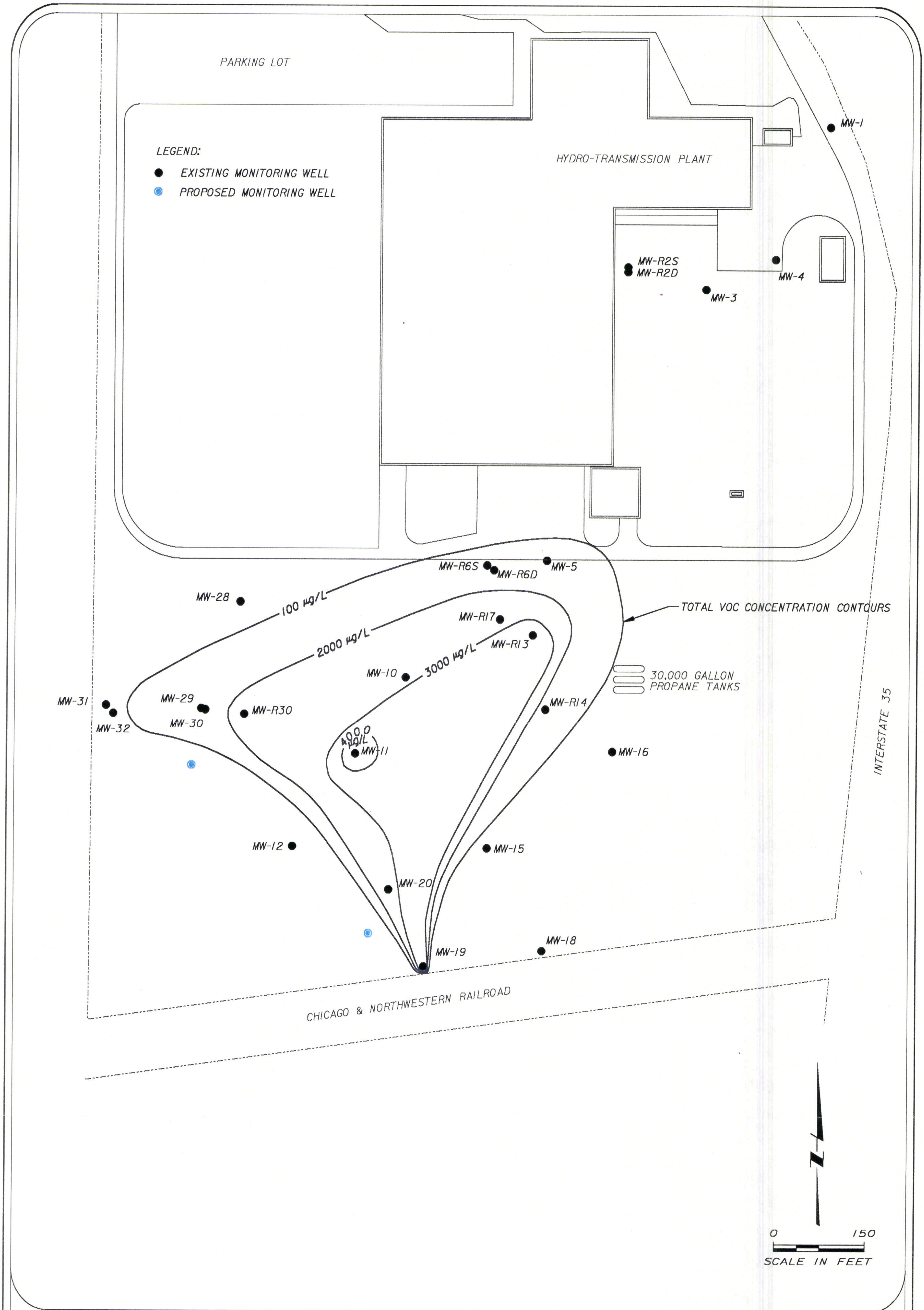
ALTERNATIVE 1 - NO ACTION/MONITOR GROUNDWATER IN AREA

Description

A sampling plan would be developed and implemented for monitoring the horizontal extent of localized groundwater constituents in select wells at the site. Monitoring wells MW-12, MW-18, MW-19, MW-20 and MW-31 would comprise the sampling network due to the presence of VOCs detected above MCLs at several of these locations during the RFI (Figure 1-2) and due to their downgradient location relative to the identified plume. Additionally, two monitoring wells would be installed, in the shallow water-bearing zone, at downgradient locations to monitor potential migration of the groundwater plume (Figure 3-1). Water samples from these wells would be analyzed for the constituents listed in Table 3-1 on an annual basis. An annual report would be prepared to summarize the results of sampling and hydrogeologic monitoring. Results of the monitoring program would be periodically reviewed and, if appropriate, modifications to the monitoring program would be recommended.

Effectiveness

<u>Human Health and the Environment</u>. According to information presented in the RFI Report, the identified VOC plume has not migrated beyond the Sauer-Sundstrand property boundary (Figure 3-1). Downgradient monitoring wells, installed as part of implementation of Alternative 1, would allow early detection of further downgradient plume movement. However, because monitoring alone would not prevent further migration of VOC concentrations in the groundwater, implementation of Alternative 1 may not, over the long term, maintain an



NOTE: DATA TAKEN FROM HARDING LAWSON ASSOCIATES JUNE 1995 REPORT

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SAUER-SUNDSTRAND FACILITY
AMES, IOWA

CONCEPTUAL LAYOUT
ALTERNATIVE 1

FIGURE 3-1

TABLE 3-1

CONSTITUENTS RECOMMENDED FOR ANALYSIS
SAUER-SUNDSTRAND FACILITY - AMES, IOWA

Constituent
1,1-Dichloroethene
1,1-Dichloroethane
cis-1,2-Dichloroethene
1,1,1-Trichloroethane
Trichloroethene
1,1,2-Trichloroethane
Tetrachloroethene

acceptable level of risk to human health and the environment. As discussed in Section 2, groundwater constituent concentrations, if ingested, would pose risks which exceed health-based benchmark levels (HI ranges from 8.86 to 11.5; range of total cancer risk levels 2.11 to 3.35); although, the likelihood of ingestion of the shallow groundwater at the site is highly remote.

Because the groundwater plume is situated close to the property boundary, there is potential for off-site migration of VOCs. However, there are no shallow groundwater drinking wells identified in the vicinity of the Sauer-Sundstrand site. The nearest known drinking well, located approximately 4,400 feet southeast of the site, is screened in glacial till at a depth of 140 feet. No city water supply wells were identified within one mile of the site. Because the site area is serviced by city water, the potential for future development of groundwater resources at the site is highly remote.

Short-Term Effectiveness. Safety considerations associated with implementation of this alternative consist of avoiding direct contact with groundwater during monitoring well installation and groundwater sampling. Use of personal protective equipment would reduce the likelihood of exposure. Existing monitoring wells at the site, in conjunction with the two proposed monitoring wells, would adequately serve to monitor any downgradient movement of the identified plume. Installation of the monitoring wells would require only a few weeks. Implementation of this alternative would be immediate. While the benefits of monitoring the area groundwater would be recognized early on, observable changes in the constituent levels and plume configuration may occur slowly. Natural attenuation of constituents may also occur over time.

Long-Term Effectiveness. Monitoring is a proven, quantifiable means of identifying changes in the groundwater quality which might impact human health or the environment. It is a reliable tool or part of a program for minimizing the potential for unacceptable levels of constituents to move off site undetected. If monitoring data would indicate the off-site migration of the VOC plume is occurring, additional corrective measures would be implemented appropriately. Additionally, some natural degradation of constituents may occur; although, many of the site constituents (chlorinated hydrocarbons) are not typically susceptible to rapid biodegradation.

Ability to Meet CMS Objectives. Groundwater monitoring alone would not prevent further migration of VOC concentrations in the groundwater. Because no reduction in the current level of risk results from implementation of Alternative 1, it would not be consistent with achieving CMS objectives.

Implementability

Alternative 1 would be implemented relatively easily. O&M requirements would be limited to conducting groundwater sampling and maintaining the monitoring well network. Once implemented, the effectiveness of this remedial alternative would be reevaluated at the end of a five-year period to determine whether CMS objectives have been fulfilled.

General federal and state requirements that may be applicable to this alternative would include the Safe Drinking Water Act and the Iowa Responsible Parties Cleanup Regulations.

Appendix A provides a more comprehensive listing and explanation of applicable regulations which may apply to individual proposed remedial alternatives for the site.

Cost

Capital costs associated with implementation of Alternative 1 are approximately $7,450. Annual O&M costs are approximately $9,250. Costs (including estimated present annualized cost) and unit breakdowns are presented in Appendix B.

ALTERNATIVE 2 -SOIL VAPOR EXTRACTION WITH AIR SPARGING/MONITOR GROUNDWATER IN AREA

Description

Vertical air sparging wells would inject air through screens into the groundwater. Sparging performs as an in-situ air stripping mechanism since the VOCs volatilize into the injected air bubbles and are carried upward to a soil vapor extraction (SVE) system. The volatilized VOCs migrate in the unsaturated zone toward vapor extraction wells where a subsurface negative pressure gradient is generated. Soil vapor removed with the SVE system would then be discharged without treatment to the atmosphere. Condensate collected from the system would be treated on site and discharged to the City of Ames POTW. Alternative 2 would be coupled with groundwater monitoring, as specified in Alternative 1 with minor changes. No additional monitoring wells would be installed as proposed in Alternative 1. Instead, select SVE/air sparging wells would be used for groundwater monitoring.

Effectiveness

Human Health and the Environment. As discussed in Section 2, groundwater constituent concentrations, if ingested, pose risks which exceed health-based benchmark levels (HI ranges from 8.86 to 11.5; range of total cancer risk levels 2.11 to 3.35). Alternative 2 would provide constituent removal from both groundwater and soil media and thereby reduce the current level of risk associated with the VOC constituents. Natural biodegradation of some constituents may also occur as oxygen is added to the subsurface environment, further reducing the mass of VOCs. However, many of the site constituents (chlorinated hydrocarbons) are not particularly susceptible to biodegradation.

While effective for removing VOCs from the groundwater, air sparging may increase the mobility of groundwater constituents at the site. Air sparging tends to mound the groundwater surface as a result of air injection under the water table and may potentially increase hydraulic gradients. Additionally, lateral spreading of air beneath low permeable zones may cause migration of soil vapors. Because the VOC plume is located close to the property boundary, there is potential for off-site migration from air sparging. Due to uncertainty regarding its ability to prevent off-site groundwater migration, it is uncertain whether Alternative 2 would maintain an acceptable level of risk to human health and the environment.

Although ingestion through drinking groundwater poses a potential route of exposure to constituents in the area, the likelihood of such exposure is remote. There are no private shallow groundwater drinking wells identified in the vicinity of the Sauer-Sundstrand site. The nearest known drinking well is located approximately 4,400 feet southeast of the site and is set in glacial till at a depth of 140 feet. No city water supply wells were identified within one mile of the site. The site area is serviced by city water; therefore, the potential for future development of groundwater resources at the site is highly remote.

Short-Term Effectiveness. Safety considerations associated with implementation of this alternative consist of avoiding direct contact with groundwater during installation of air sparging and SVE wells, associated construction, O&M activities, and groundwater sampling. Use of personal protective equipment would reduce the likelihood of exposure. Alternative 2 would require approximately six months to implement. Once installed, removal of the VOC mass from the groundwater would be immediate. It may require several weeks to assess the overall system effectiveness through activities such as measuring vacuum pressure and possibly sampling the discharge air stream for VOCs. If necessary, flow rates of the SVE and air sparging wells could be adjusted to allow flexibility in system operation. Extraction rates could be modified to vary in accordance with site conditions and changes in constituent levels.

Long-Term Effectiveness. The long-term effectiveness of air sparging would be difficult to predict. Although air sparging could quickly reduce constituent levels in the shallow groundwater and may enhance some natural biological degradation, sparging the groundwater could create preferential bubble pathways that limit mass transfer effectiveness. In light of the observed subsurface heterogeneity at the site, air sparging may have limited ability to effectively reach constituents present above low permeable zones. Additionally, sand lenses could further slow the SVE removal process by concentrating air flow through higher permeability zones. Periodically shutting the system down may improve the performance by redirecting soil gas pathways.

While some remedial components are susceptible to fouling, clogging, and wear, which may reduce their removal efficiency and reliability; proper maintenance would mitigate this vulnerability. If properly maintained, the system blowers and compressors may have a useful life of approximately five years. Constituent concentrations would likely reach asymptotic levels within five years, so use of the system would likely be discontinued.

Ability to Meet CMS Objectives. Air sparging coupled with SVE would serve to reduce constituent concentrations in the impacted area of the site. However, inherent risks of increasing constituent mobility associated with this alternative must be considered. Due to uncertainty associated with its ability to prevent off-site constituent migration, Alternative 2 may not be consistent with achieving CMS objectives.

Implementability

A considerable design effort would be required to implement the air sparging and SVE technology effectively because subsurface heterogeneities would significantly influence the areal impact and placement of the air sparging and SVE wells. Based upon the observed heterogeneity in the site geology, it would be difficult to identify discontinuous sand units which may limit the effectiveness of this technology. An assessment of the potential effect on groundwater flow directions and constituent transport would likely be required. Hydrogeologic monitoring of the groundwater system would be necessary to evaluate groundwater flow directions and possible new routes of constituent migration.

The air sparging and SVE wells would be mechanically simple to install, as needed, to achieve proper coverage at the site. Contractors and vendors capable of supplying assistance and support for implementation of the system are available. The conceptual SVE well placement is assumed, based upon previous experience, to be in a grid pattern with an estimated radius of impact of approximately 50 feet as shown in Figure 3-2. Air sparging well placement is assumed to be in a grid pattern similar to that of the SVE wells (Figure 3-2). These estimates assume the sand layers are continuous. Actual conditions may have the effect of increasing or decreasing the effective radius of the wells. The degree to which subsurface heterogeneities would impact the wells would have to be assessed for the system to be appropriately configured. Conveyance piping would be placed below ground surface.

Maintenance requirements of this alternative would include monitoring the effectiveness of the air sparging and SVE system, and maintaining the vacuum and compressor systems. Groundwater sampling and hydraulic monitoring would also be required; therefore, the monitoring well network would also have to be maintained. No new monitoring wells would be installed as part of implementation of Alternative 2 Instead, select SVE wells would be used for groundwater monitoring in conjunction with existing wells. Once implemented, the effectiveness of this remedial alternative would be reevaluated at the end of a five-year period to determine whether CMS objectives have been fulfilled.

General federal and state requirements that may be applicable to this alternative would include the Safe Drinking Water Act and the Iowa Responsible Parties Cleanup Regulations. Appendix A provides a more comprehensive listing and explanation of applicable regulations which may apply to individual proposed remedial alternatives for the site.

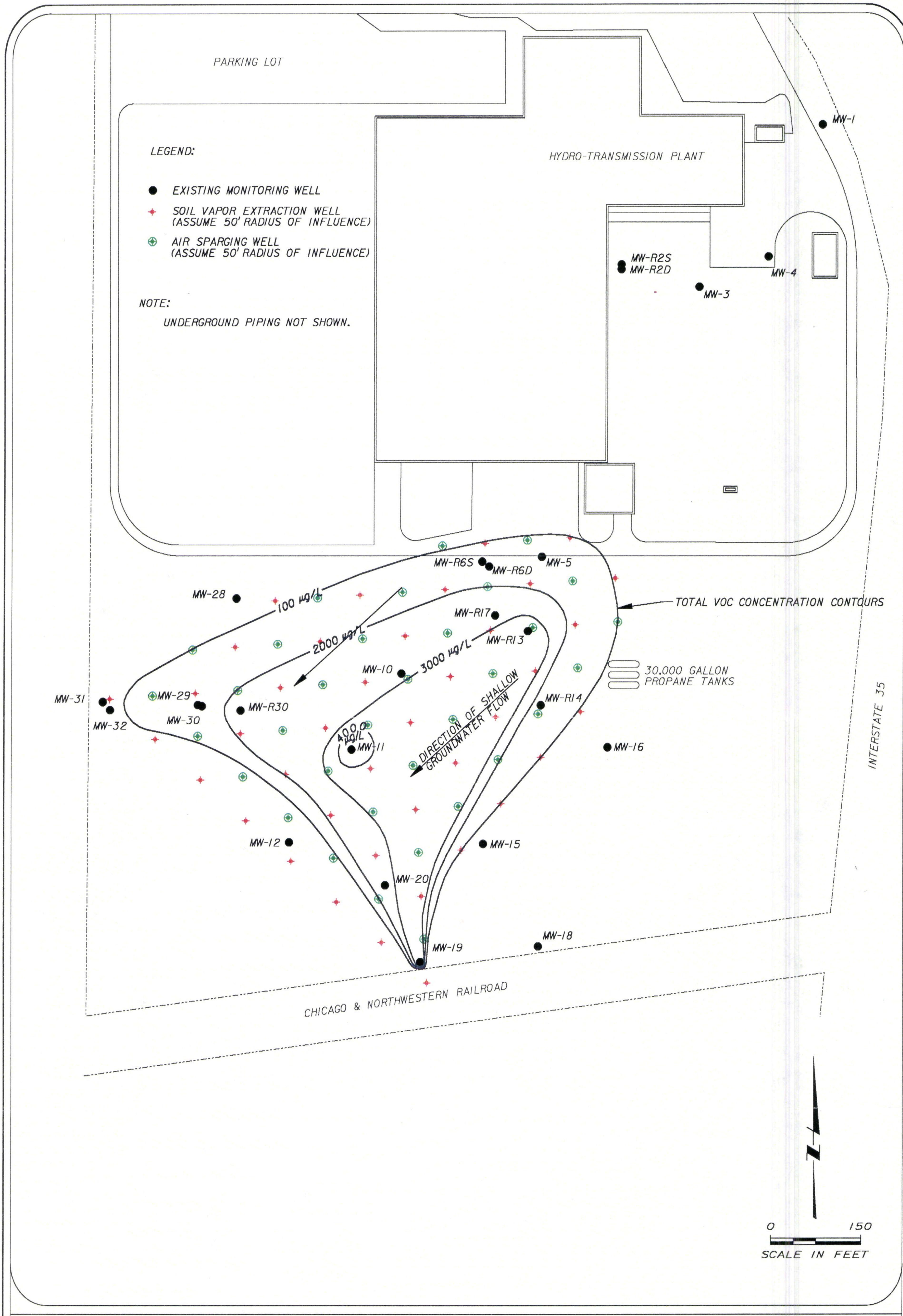
Cost

Capital costs associated with implementation of Alternative 2 are approximately $1,572,600. Annual O&M costs are approximately $320,500. Costs (including estimated present annualized cost) and unit breakdowns are presented in Appendix B.

ALTERNATIVE 3 - GROUNDWATER EXTRACTION WELLS/DISCHARGE TO LOCAL POTW/MONITOR GROUNDWATER IN AREA

Description

The objective of the extraction wells would be to remove impacted groundwater and provide hydraulic control of the VOC plume. Approximately 19 shallow extraction wells would be placed along the leading edge of the identified VOC plume (Figure 3-3). A groundwater ejector system which uses the ejector (or jet pump) principal would be used to collect impacted groundwater. The groundwater would then be discharged to the sanitary sewer in accordance with conditions established by the City of Ames Publicly Owned Treatment Works (POTW).



NOTE: DATA TAKEN FROM HARDING LAWSON ASSOCIATES JUNE 1995 REPORT

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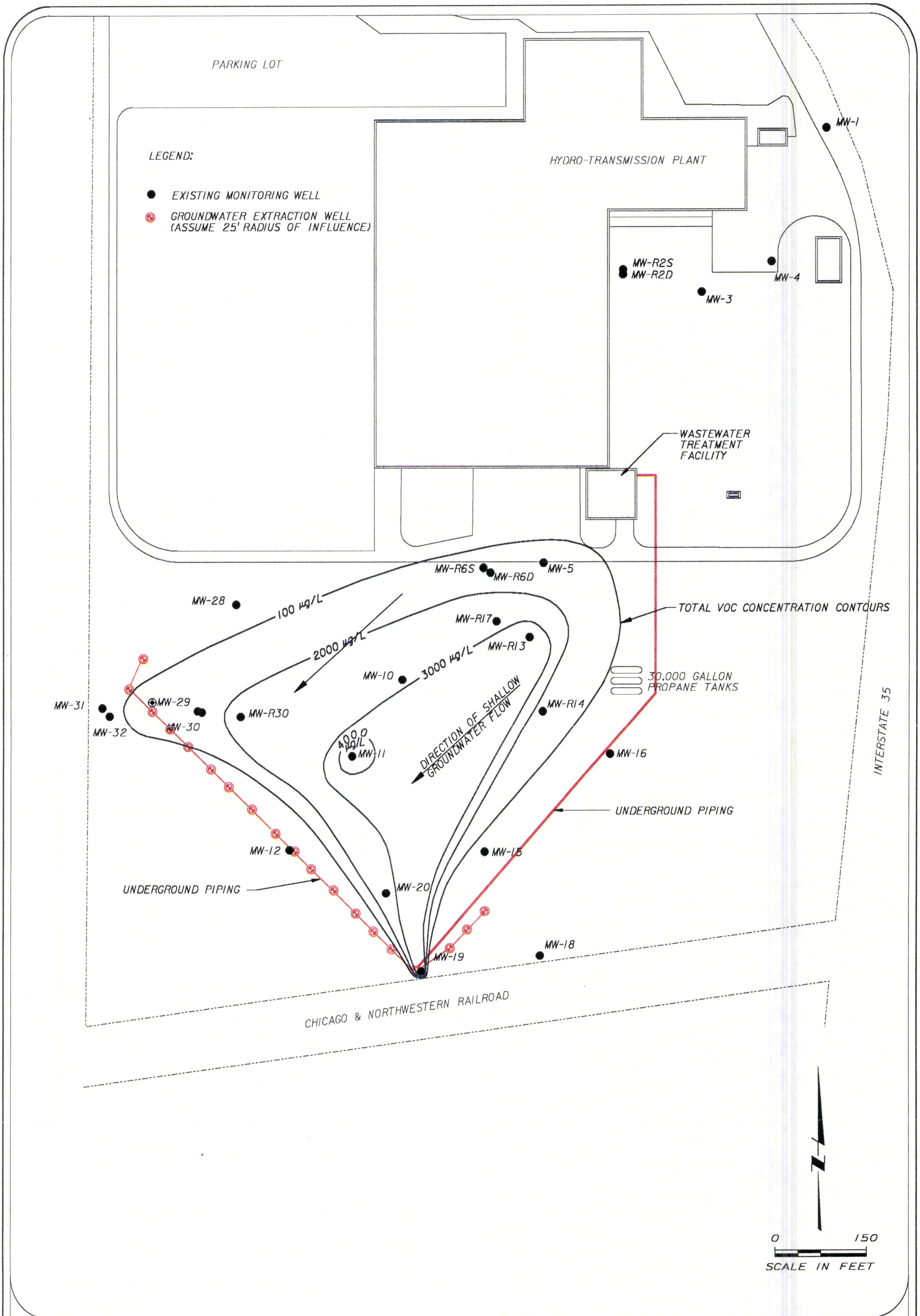
CONCEPTUAL LAYOUT
ALTERNATIVE 2

FIGURE 3-2



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AMES, IOWA

CONCEPTUAL LAYOUT
ALTERNATIVE 3

FIGURE 3-3

AB100

A centrifugal pump would be used to continuously circulate water through the system at a relatively high pressure. At each well point, circulating water would pass through a venturi, creating a vacuum and thereby extracting groundwater. Conveyance piping would be placed underground to link the extraction wells with associated remedial system components. A surge tank placed between the last extraction well and the centrifugal pump would provide recirculation water for the system. The overflow from the surge tank would be directly discharged to the City of Ames POTW through the sanitary sewer inlet located in the existing wastewater treatment facility. The surge tank and associated components would be housed within the existing wastewater treatment facility and would be designed to accommodate a design flow rate of 10-15 gallons per minute (gpm). Based upon hydraulic conductivities provided in the RFI report, the estimated groundwater capture from the extraction wells would provide a steady state influent flow rate of approximately 5 gpm. Groundwater monitoring, as described in Alternative 1 with minor changes, would also be incorporated into implementation of Alternative 3. No additional monitoring wells would be installed as proposed in Alternative 1. Instead, select extraction wells would be used for groundwater monitoring in conjunction with existing wells.

Effectiveness

Human Health and the Environment. Groundwater monitoring has indicated that the identified VOC plume is migrating toward the southwest in the direction of shallow groundwater flow. Extraction wells would be strategically located to intercept the plume as it moves downgradient and mitigate off-site constituent migration (Figure 3-3). Groundwater constituent concentrations, if ingested, pose risks which exceed health-based benchmark levels (HI ranges from 8.86 to 11.5; range of total cancer risk levels 2.11 to 3.35). Implementation of Alternative 3 would maintain an acceptable level of risk to human health and the environment by removing impacted groundwater from the site.

While groundwater ingestion poses a potential exposure route, the likelihood of such exposure is unlikely. There are no private shallow groundwater drinking wells identified in the vicinity of the Sauer-Sundstrand site. The nearest known drinking well is located approximately 4,400 feet southeast of the site and is set in glacial till at a depth of 140 feet. No city water supply wells were identified within one mile of the site. The site area is serviced by city water; therefore, the potential for future development of groundwater resources at the site is highly remote.

Short-Term Effectiveness. Safety considerations associated with implementation of this alternative consist of avoiding direct contact with groundwater during sampling, well installation, associated remedial system construction, and O&M activities. Use of personal protective equipment would reduce the likelihood of exposure.

Alternative 3 may require approximately six months to implement. Once the extraction wells are operational, constituent removal would be immediate. It is uncertain how quickly the hydraulic benefit of the extraction wells would be fully recognized. Pump testing and ongoing hydrogeologic monitoring would be required to determine the effectiveness of the extraction wells and to identify the hydraulic impact resulting from implementation of this alternative.

Long-Term Effectiveness. Groundwater extraction wells are a proven means of removing impacted groundwater. The extraction well pumping rates could be adjusted to allow flexibility in the system operation. Pumping rates could be modified to vary according to site conditions or changing constituent levels. While some remedial components are susceptible to fouling, clogging, and wear, which may reduce their removal efficiency and reliability; proper maintenance would mitigate this vulnerability. If properly maintained, the conveyance pumps and ejectors may operate effectively for approximately five years.

It will be difficult to predict the long-term effectiveness of Alternative 3 because the subsurface heterogeneity at the site will reduce the performance of the groundwater extraction wells. The presence of sand lenses will be problematic in terms of achieving adequate capture of constituents within zones of lower conductivity. Preferential groundwater collection pathways may develop and short-circuit constituent removal. Once sand layers are dewatered, it will be difficult to remove and capture from the less permeable surrounding clay soil material.

Ability to Meet CMS Objectives. Implementation of Alternative 3 would be consistent with achieving CMS objectives. Removal and capture of the groundwater would reduce the current level of risk associated with VOCs in the source area and mitigate future off-site migration of the shallow groundwater plume.

Implementability

A design effort, including pump testing, would be required to implement Alternative 3. Based upon previous experience with similar site conditions, the estimated effective radius of impact of the extraction wells is approximately 25 feet (Figure 3-3). Subsurface heterogeneities would likely affect the performance of the extraction wells; therefore, the degree to which their effectiveness would be impacted would have to be assessed in order for the system to be appropriately configured.

The extraction wells and associated remedial equipment could be easily installed. Contractors and vendors are available to provide required materials and support for implementation. The remedial system would require routine monitoring and maintenance of moving parts (pumps) and ejectors. Groundwater sampling, and hydraulic monitoring, would also be required to verify the remedial alternative's performance. Therefore, the monitoring well network also would need to be maintained. Once implemented, the effectiveness of this remedial alternative would be reevaluated at the end of a five-year period to determine whether CMS objectives have been fulfilled.

General federal and state requirements that may be applicable to this alternative would include the Safe Drinking Water Act, Iowa Water Pollution Control Regulations, and Iowa Responsible Parties Cleanup Regulations. Appendix A provides a more comprehensive listing and explanation of applicable regulations which may apply to individual proposed remedial alternatives for the Sauer-Sundstrand site.

Cost

Capital costs associated with implementation of Alternative 3 are approximately $433,440. Annual O&M costs are approximately $54,600. Costs (including estimated present annualized cost) and unit breakdowns are presented in Appendix B.

ALTERNATIVE 4 - GROUNDWATER INTERCEPTION TRENCH/DISCHARGE TO LOCAL POTW/MONITOR GROUNDWATER IN AREA

Description

Approximately 900 feet of trench with collection piping would be installed along the leading edge of the shallow groundwater VOC plume. This trench would allow collection of impacted groundwater and provide hydraulic control of the groundwater plume.

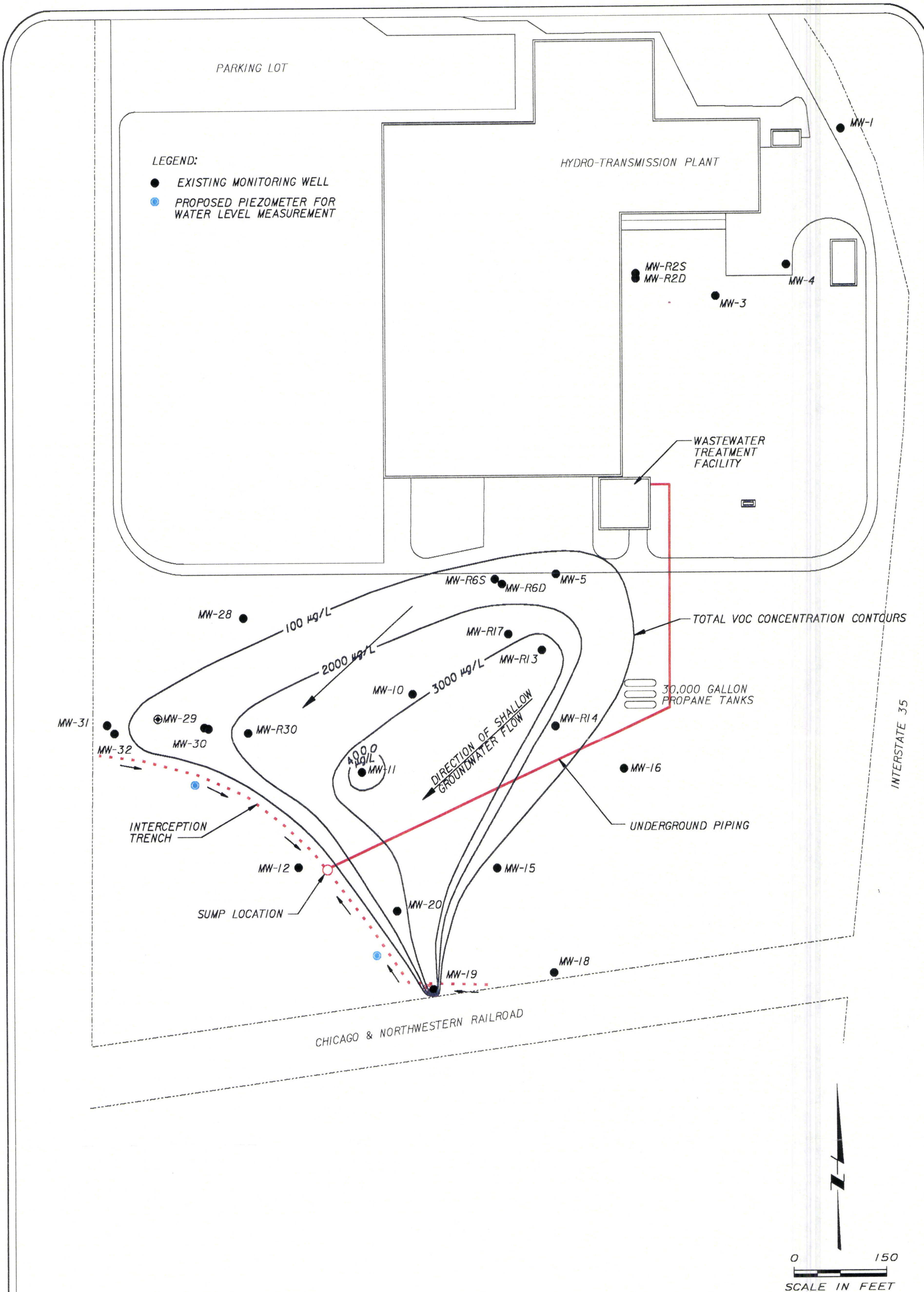
The interception trench would extend to a depth of approximately 25 feet (depth will vary depending on the ground surface elevation and slope of the trench). A perforated pipe would be placed near the bottom of the trench and sloped to a central sump location. The trench would be backfilled with granular fill to create a more permeable zone for water to flow. The upper portion of the trench would be backfilled and recompacted with native soils to mitigate seepage of surface water into the installed trench. Conveyance piping would tie into the sanitary sewer inlet located in the existing wastewater treatment facility. Groundwater intercepted by the trench would be directly discharged to the sanitary sewer in accordance with conditions established by the City of Ames POTW. Groundwater monitoring, as described in Alternative 1, would also be included in implementation of Alternative 4 with minor changes.

No new monitoring wells would be installed under implementation of Alternative 4. Two piezometers for monitoring gradient control would be installed approximately 50-75 feet from the interception trench. These piezometers, in conjunction with existing monitoring wells, would be used to evaluate the hydraulic performance of the interception trench.

Effectiveness

Human Health and the Environment. As presented in the RFI Report, the VOC plume appears to be migrating toward the southwest in the direction of shallow groundwater flow. The groundwater trench would be located along the downgradient edge of the plume to provide constituent removal and hydraulic control of the shallow groundwater (Figure 3-4). Groundwater gradients would converge on the trench system and provide effective capture of the leading edge of the identified plume.

As discussed in Section 2, the groundwater constituent concentrations, if ingested, pose risks which exceed health-based benchmark levels (HI ranges from 8.86 to 11.5; range of total cancer risk levels 2.11 to 3.35). While there is potential for exposure through ingesting groundwater, the likelihood of such exposure is remote. No private shallow groundwater drinking wells were identified in the vicinity of the Sauer-Sundstrand site. The nearest known drinking well, located approximately 4,400 feet southeast of the site, is set in glacial till at a depth of 140 feet. Additionally, no city water supply wells were identified within one mile of the site. Because the site area is serviced by city water, the potential for future development of groundwater resources at the site is highly remote. By removing impacted groundwater, the current level of risk associated with the site would be reduced. Therefore, implementation of Alternative 4 would maintain an acceptable level of risk to human health and the environment.



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AMES, IOWA

CONCEPTUAL LAYOUT
ALTERNATIVE 4

FIGURE 3-4

Short-Term Effectiveness. Safety considerations associated with implementation of this alternative consist of avoiding direct contact with groundwater during sampling, trench installation, associated remedial system construction, and O&M activities. Particular care would be undertaken during trenching activities, since this operation poses the greatest potential for exposure to constituents through direct contact. Use of personal protective equipment would reduce the likelihood of exposure.

Alternative 4 may require approximately six months to implement. Once the interception trench is operational, constituent removal would be immediate. It is uncertain how quickly the hydraulic benefit of the trench would be fully recognized. However, because the trench allows interception from both high permeability (sand lenses) and lower permeability zones (glacial till), this groundwater collection technology will prove effective in capturing the shallow groundwater and minimizing off-site migration potential. Monitoring of the piezometers and monitoring wells will be used to assess the effectiveness of the trench.

Long-Term Effectiveness. Groundwater capture with an interception trench is a proven technology, and the system would be mechanically simple to implement. While some remedial components are susceptible to fouling, clogging, and wear, which may reduce their removal efficiency and reliability, proper maintenance would mitigate this vulnerability. If properly maintained, the conveyance pumps may function effectively for approximately five years. With proper cleaning, the trench could be maintained for a much longer period.

Because an interception trench allows groundwater capture from zones of varying permeability, the long-term performance is most reliable. As the clay soils and sand stringers are dewatered, it is anticipated that groundwater flow from the trench will stabilize at approximately 5-10 gpm based upon similar project experience. Hydrogeologic monitoring of wells will be used to measure the hydraulic impact over time. Because the trench is a passive system, flexibility in modifying the system according to constituent concentrations or other variable site conditions would be limited. If necessary, some modification may be achieved through adjusting the extraction rate from the collection sump pump.

Ability to Meet CMS Objectives. Implementation of Alternative 4 would be consistent with achieving CMS objectives. Passive collection of impacted groundwater would reduce the current level of risk associated with VOCs in the source area and mitigate future off-site migration of the shallow groundwater plume.

Implementability

A design effort would be required to determine the trench configuration and conveyance system specifications. Contractors and vendors are readily available to provide materials and services required for implementation. The trench would be installed using a special trenching machine that excavates the trench, inserts the drainage pipe, and backfills the trench with sand and/or gravel in one continuous operation. This installation method provides rapid and cost-effective trench construction to depths up to 25 feet below grade. This method eliminates the need for shoring and dewatering activities associated with traditional trench construction activities which can be expensive and pose safety concerns.

The remedial system would require routine monitoring and maintenance of moving parts (pumps). Groundwater sampling and hydraulic monitoring would also be required to verify the remedial alternative's performance. Therefore, the monitoring well network also would need to be maintained. Once implemented, the effectiveness of this remedial alternative would be reevaluated at the end of a five-year period to determine whether CMS objectives have been fulfilled.

General federal and state requirements that may be applicable to this alternative would include the Safe Drinking Water Act, Iowa Water Pollution Control Regulations, and Iowa Responsible Parties Cleanup Regulations. Appendix A provides a more comprehensive listing and explanation of applicable regulations which may apply to individual proposed remedial alternatives for the Sauer-Sundstrand site.

Cost

Capital costs associated with implementation of Alternative 4 are approximately $276,400. Annual O&M costs are approximately $40,100. Costs (including estimated present annualized cost) and unit breakdowns are presented in Appendix B.

SECTION 4

SECTION 4

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents a comparative analysis of the remedial alternatives described in Section 3 for addressing VOCs in groundwater at the Sauer-Sundstrand site. The remedial alternatives are evaluated in relation to one another in order to identify the relative advantages and disadvantages of each. A summary of the evaluation criteria for the source area remedial alternatives is presented in Tables 4-1 and 4-2. Cost estimates for each alternative are included as Appendix B.

EFFECTIVENESS

Human Health and the Environment

The risk assessment indicates current concentrations of constituents of concern at the site would pose an unacceptable risk to human health if ingested. Therefore, only alternatives which reduce the current level of constituent concentrations at the site would be consistent with achieving the overall CMS objectives of protecting human health and the environment and minimizing off-site migration of the groundwater plume.

Alternative 1 which consists of monitoring groundwater in the area would allow early identification of changes in groundwater quality which might adversely impact human health or the environment. However, this alternative neither serves to reduce the concentration of constituents in the identified plume nor does it provide any measures to mitigate off-site plume migration. Due to these shortcomings, Alternative 1 would not be consistent with achieving CMS objectives.

Air sparging with SVE would be employed through implementation of Alternative 2. Although this technology would likely provide constituent removal from the source area, air sparging tends to mound the groundwater surface as a result of air injection under the water table. This mounding effect may increase hydraulic gradients and potentially enhance groundwater mobility. Additionally, lateral spreading of the air beneath low permeability zones may cause migration of VOC vapors. Because the VOC plume is located close to the property boundary, there is potential for off-site constituent migration to occur in response to air sparging. Due to uncertainty regarding its ability to prevent off-site constituent migration, Alternative 2 is not considered to be consistent with achieving CMS objectives.

Alternatives 3 and 4 employ technologies which would remove impacted groundwater from the VOC plume and thereby reduce the risk associated with the current level of constituents at the site. Both alternatives would intercept impacted groundwater for direct discharge to the sanitary sewer. Final treatment would be completed at the City of Ames POTW. The major difference between the two alternatives is that Alternative 3 uses groundwater extraction with recovery wells, while Alternative 4 relies upon groundwater collection with an interception trench.

TABLE 4-1

SUMMARY OF HUMAN HEALTH AND ENVIRONMENTAL EVALUATION OF REMEDIAL ALTERNATIVES
SAUER - SUNDSTRAND FACILITY - AMES, IOWA

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Description	No Action/Monitor Groundwater in Area	Soil Vapor Extraction (SVE)/Air Sparging. Monitor Groundwater in Area	Groundwater Extraction Wells/ Discharge to POTW/ Monitor Groundwater in Area	Groundwater Collection Trench/ Discharge to POTW/ Monitor Groundwater in Area
Ability to Meet CMS Objectives	Monitoring would not prevent further migration of constituents in groundwater; therefore, Alternative 1 would not be consistent with CMS objectives.	SVE with air sparging would effectively provide constituent removal from both the groundwater and soil media. However, there are risks of spreading the VOC plume associated with implementation of this alternative. Therefore, Alternative 2 may not be consistent with meeting CMS objectives.	Extraction wells would provide removal of impacted groundwater and prevent further migration of the VOC plume.	Collection with a trench would provide removal of groundwater and prevent further migration of the VOC plume.
Long-Term Effectiveness	Monitoring is a proven, quantifiable means of identifying changes in the groundwater quality which might impact human health or the environment. This alternative would prevent undetected off-site migration of the VOC plume.	Sparging performs as an in-situ air stripping mechanism as soil and groundwater constituents volatilize into the injected air bubbles and are carried upward and removed through a soil vapor extraction system. It is difficult to predict the long-term effectiveness of this alternative due to the subsurface heterogeneity observed at the site.	Extraction wells would provide hydraulic control of the VOC plume by allowing collection of impacted groundwater for direct discharge to the City of Ames Publicly Owned Treatment Works (POTW). It is questionable whether this method would intercept all of the isolated shallow water bearing sand at the site.	A groundwater collection trench would provide hydraulic control of the constituent plume by allowing collection of impacted groundwater for direct discharge to the City of Ames POTW.

TABLE 4-1 (CONTINUED)

SUMMARY OF HUMAN HEALTH AND ENVIRONMENTAL EVALUATION OF REMEDIAL ALTERNATIVES
SAUER - SUNDSTRAND FACILITY - AMES, IOWA

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Short-Term Effectiveness	Installation of new monitoring wells would require approximately two weeks. Monitoring would then be immediately implementable and effective for documenting changes in groundwater quality over time.	Installation of air sparging and SVE wells would require approximately six months to implement. Once operational, constituent removal would be immediate.	Installation of groundwater extraction wells and associated conveyance equipment would require approximately six months to implement. Once operational, constituent removal would be immediate. It is uncertain how quickly hydraulic benefits would be fully recognized.	Installation of a groundwater extraction trench and associated conveyance equipment would require approximately six months to implement. Once operational, constituent removal would be immediate. It is uncertain how quickly hydraulic benefits would be fully recognized.
Adverse Effects	Potential exposure exists for direct contact with groundwater during sampling and operation and maintenance activities.	Potential exposure exists for direct contact with groundwater during sampling, well installation, construction, and operation and maintenance activities. Air sparging tends to mound the groundwater surface as a result of air injection under the water table. This effect may increase constituent mobility.	Potential exposure exists for direct contact with groundwater during sampling, well installation, construction, and operation and maintenance activities. Subsurface heterogeneity may adversely impact the overall effectiveness of the extraction wells.	Potential exposure exists for direct contact with groundwater during sampling, trenching activities, associated construction, and operation and maintenance activities.
Measures to Mitigate Adverse Effects	Use of personal protective equipment would reduce the likelihood of exposure.	Use of personal protective equipment would reduce the likelihood of exposure.	Use of personal protective equipment would reduce the likelihood of exposure.	Use of personal protective equipment would reduce the likelihood of exposure.

CMS = Corrective Measures Study

TABLE 4-2

SUMMARY OF IMPLEMENTABILITY EVALUATION OF REMEDIAL ALTERNATIVES
SAUER - SUNDSTRAND FACILITY - AMES, IOWA

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Description	No Action/Monitor Groundwater in Area	Soil Vapor Extraction (SVE)/Air Sparging. Monitor Groundwater in Area	Groundwater Extraction Wells/ Discharge to POTW/ Monitor Groundwater in Area	Groundwater Collection Trench and Treatment/ Discharge to POTW/ Monitor Groundwater in Area
Ability to Perform Intended Function and Reduce Residual Risk	Effective in documenting changes in groundwater quality over time. Further migration would be quickly detected and corrective measures implemented if warranted.	Effective in reducing exposure risk by removing volatile organic compounds (VOCs) from the groundwater and soil media. System allows flexibility to adapt to variable site conditions.	Effective in reducing exposure risk by providing active removal and hydraulic control of impacted groundwater using extraction wells. Allows flexibility to adapt to variable site conditions.	Effective in reducing exposure risk by providing passive hydraulic control of groundwater. A trench would allow interception of both high and low permeability zones for groundwater collection.
Useful Life	A five-year review would be necessary to evaluate performance.	A five-year review would be necessary to evaluate performance.	A five-year review would be necessary to evaluate performance.	A five-year review would be necessary to evaluate performance.
Operation and Maintenance	Groundwater sampling. Maintain groundwater monitoring well network.	Requires routine groundwater and system monitoring and maintenance due to moving parts. Monitoring well network must be maintained. Air sparging and SVE wells have potential for fouling. Treatment system blowers and compressors may have a useful life of approximately five to ten years.	Requires routine groundwater and system monitoring and maintenance due to moving parts. Monitoring well network must be maintained. Groundwater extraction wells may be subject to fouling. Conveyance pumps may have a useful life of approximately five years.	Requires routine groundwater and system monitoring and maintenance due to moving parts. Monitoring well network must be maintained. Conveyance pumps may have a useful life of approximately five years.

TABLE 4-2 (CONTINUED)

SUMMARY OF IMPLEMENTABILITY EVALUATION OF REMEDIAL ALTERNATIVES
SAUER - SUNDSTRAND FACILITY - AMES, IOWA

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Reliability	Proven, quantifiable means of monitoring changes in groundwater quality. Only slight modifications would be necessary to ensure the existing monitoring well network is adequate for detecting groundwater changes over time.	Long-term effectiveness is difficult to predict. Air injection under the water table may increase constituent mobility and create lateral spreading of constituents. Monitoring would detect changes in groundwater quality over time.	Proven means of containing and intercepting groundwater. Effectiveness of extraction wells may be limited by subsurface heterogeneity. Monitoring would detect changes in groundwater quality over time.	Proven means of containing and intercepting groundwater. Limited moving parts. Able to intercept water from both high and low permeability zones. Monitoring would detect changes in groundwater quality over time.
Constructability	Requires construction of two monitoring wells. Requires maintenance of existing monitoring well network.	Mechanically simple to implement. Requires a design effort to achieve proper coverage at the site. System will have operation and maintenance (O&M) requirements due to moving parts. Requires maintenance of monitoring well network.	Mechanically simple to implement. A design effort would be required for well placement and selection of conveyance system components. Sanitary sewer inlet is available in existing wastewater treatment facility. Remedial system components may be housed within existing wastewater treatment facility. System will have O&M requirements due to moving parts. Require maintenance of monitoring well network.	Mechanically simple to implement. A design effort would be required to determine most effective placement of trench and select conveyance system components. Sanitary sewer inlet is available in existing wastewater treatment facility. System will have O&M requirements due to moving parts. Requires maintenance of existing monitoring wells.

Although the ability to vary pumping rates of the extraction wells would allow greater flexibility in operation of the remedial system, constituent removal by this method of groundwater extraction is limited due to subsurface heterogeneities at the site. The presence of isolated sand lenses within a dense, clay-rich glacial till will reduce the performance of the extraction wells if the sand layers are dewatered. Preferential flow pathways may develop in higher permeability zones during pumping and make constituent removal from surrounding less permeable zones more difficult. Because a trench would intersect zones of both high permeability (sand lenses) and lower permeability (glacial till) sediments, Alternative 4 would provide more reliable capture of the impacted groundwater.

In addition to providing constituent removal, Alternatives 3 and 4 also allow hydraulic control of the shallow groundwater plume. Alternative 4 may be more effective in providing hydraulic control than Alternative 3, because the performance of an interception trench is not as sensitive to the geologic variations of the subsurface environment as extraction wells.

Short-Term Effectiveness

Implementation of any of the alternatives would result in a potential risk of direct contact exposure to groundwater during sampling and routine O&M activities. Additional exposure would result in those alternatives which require intrusive construction. Alternatives 2 and 3 pose risks of direct contact exposure during well installation and associated construction. Risk of direct exposure is also associated with the excavation and construction required for implementation of Alternative 4. Because trenching activities create the greatest potential for direct contact with constituents, particular care would be undertaken during this activity. It should be noted that a special trenching tool, as described in Section 3, would be employed in implementation of Alternative 4 to mitigate exposure risks traditionally associated with trenching activities. Use of personal protective equipment would reduce the potential for exposure posed by any of the Alternatives.

Alternative 1 would require very little construction; therefore, it is virtually immediately implementable and would provide immediate results. Alternatives 2, 3 and 4 would all require more complex construction and include a design element. Implementation of each of these alternatives would likely require approximately six months to complete. Upon their completion, constituent removal would likely begin immediately. An extended period of time, several weeks or possibly months, may be required to assess the hydrogeologic impacts of their implementation.

Long-Term Effectiveness

Alternative 1 would allow documentation of changes in groundwater quality over time; however, no reduction in the level of constituent concentrations at the site would be associated with its implementation other than some concentration reductions which may occur through biodegradation. It is difficult to assess the long-term impact of Alternative 2. While air sparging with SVE may provide effective VOC removal, the risk of spreading the groundwater plume associated with its implementation would be a significant drawback regarding the long-term effectiveness of this alternative. Alternatives 3 and 4 would both reduce the level of constituent concentrations at the site boundary by removing impacted groundwater. These alternatives would also provide hydraulic control of shallow groundwater and mitigate the potential for off-site plume migration.

Based on the hydrogeologic conditions at the site, Alternative 4 may provide the most effective means of intercepting the shallow groundwater VOC plume. Unlike extraction wells, the performance of a trench would not be limited by the subsurface heterogeneity. Intercepting both high and low permeability zones would facilitate more reliable groundwater collection and constituent mass removal. Over time, a trench may have a greater radius of influence on the overall groundwater system than the extraction wells.

IMPLEMENTABILITY

Alternative 1 would require only minimal construction. To provide a sufficient monitoring well network, two monitoring wells would be installed downgradient of the identified VOC plume (Figure 3-1). Alternatives 2, 3 and 4 would involve considerable construction and would require a design effort to implement. These alternatives would be mechanically simple to construct, and contractors and vendors are available for providing labor, materials and technical support.

Approximately 40 SVE wells and 30 air sparging wells would be required to provide adequate coverage over the extent of the VOC plume for implementation of Alternative 2 (Figure 3-2). A system of conveyance piping would be constructed beneath the ground surface to interconnect the SVE and air sparging wells and link them with associated remedial components (i.e., blowers, compressors).

Alternative 3 would be relatively simple to construct. Approximately 19 shallow extraction wells would be installed along the leading edge of the plume in the southwestern corner of the site (Figure 3-3). Because there are no moving parts associated with the ejectors at the well points, maintenance of these components would be minimal. Transport piping would be placed underground to link the extraction wells with the sanitary sewer inlet located in the existing wastewater treatment facility. The collected groundwater would be treated at the City of Ames POTW.

Construction of Alternative 4 would also be relatively simple to implement. Similar to the extraction wells in Alternative 3, the groundwater interception trench would be located in the southwestern corner of the site along the downgradient boundary of the identified plume (Figure 3-4). A special trenching machine would be used to construct the trench. The machine would excavate, insert the drainage pipe, and backfill the trench with sand and/or gravel in one continuous operation. Because this method eliminates the need for shoring and dewatering activities typically associated with traditional trench construction activities, the safety concerns and expense associated with implementation of Alternative 4 would be reduced. Intercepted groundwater would be directly discharged to the sanitary sewer through the inlet located in the existing wastewater treatment facility. The groundwater would then be treated at the City of Ames POTW.

COST

Capital costs associated with Alternative 1 are $7,450. O&M costs would be approximately $36,940 for a five-year period. The estimated total project costs would be $44,390.

Alternative 2 has capital cost requirements of approximately $1,572,600. Associated O&M costs would be approximately $1,280,000 for a five-year period. The total estimated project cost would equal $2,852,600.

Alternative 3 would cost approximately $433,440 and $218,000 for capital and five-year O&M costs, respectively. The total project cost would be approximately $651,440.

Capital costs associated with Alternative 4 are approximately $276,400. O&M requirements over a five-year period would cost approximately $160,100 The estimated total project cost would equal $436,500.

SECTION 5

SECTION 5

RECOMMENDATION FOR FINAL CORRECTIVE MEASURE ALTERNATIVE

The following section presents a recommendation for the corrective measure alternative to be selected for implementation at the Sauer-Sundstrand site. This recommendation is made based on the following considerations:

- The effectiveness of the remedial alternative to protect human health and the environment.
- The performance of the alternative in terms of controlling and minimizing off-site migration of groundwater containing constituent concentrations that represent an unacceptable human health or environmental risk.
- The ability of the remedial alternative to comply with applicable state and federal regulations.
- The implementability and cost effectiveness of the alternative.

RECOMMENDATION OF CORRECTIVE MEASURE

Alternative 4, which consists of constructing a groundwater interception trench and directly discharging impacted groundwater to the sanitary sewer for treatment at the City of Ames POTW, is recommended for implementation at the Sauer-Sundstrand site. This alternative also includes conducting area groundwater monitoring as described in Alternative 1.

This alternative would be consistent with achieving CMS objectives, since the removal of impacted groundwater would reduce the current level of risk associated with groundwater at the site. Additionally, Alternative 4 provides hydraulic control of the shallow groundwater VOC plume and mitigates the potential for off-site migration.

Because the performance of a groundwater trench would not be limited by subsurface heterogeneities, this technology is the most suitable selection for implementation at the site. The ability of Alternative 4 to provide reliable, effective capture and hydraulic control of the groundwater plume distinguishes this alternative as the most cost effective means of achieving the CMS objectives.

Alternative 4 would be mechanically simple to implement. Vendors and contractors are available to provide required labor, materials and technical support. A special trenching machine would be used to expedite construction and reduce the safety concerns and expense associated with traditional trenching activities (shoring, dewatering). Use of personal protective equipment would reduce the likelihood of direct contact exposure to site constituents during implementation and O&M activities.

In summary, Alternative 4 will meet the overall objectives of CMS activities by maintaining an acceptable level of risk to human health and the environment. The recommended alternative is a proven, appropriate, cost effective means of achieving CMS goals.

APPENDIX A

APPENDIX A

POTENTIAL APPLICABLE RULES AND REGULATIONS

Standard, Requirement, Criteria or Limitation	Citation	Description
FEDERAL		
Safe Drinking Water Act	40 USC Section 300	
National Primary Drinking Water Standards	40 CFR Part 141	Establishes maximum contaminant levels (MCLs) which are health-based standards for public water systems.
National Pretreatment Standards	40 CFR Part 403	Sets standards to control pollutants which pass through or interfere with treatment processes in publicly-owned treatment works or which may contaminate sewage sludge.
Occupational Safety and Health Act	20 USC Section 651-678	Regulates worker health and safety.
Clean Air Act	42 USC Section 7401-7642	
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Establishes standards for ambient air quality to protect public health and welfare.
STATE		
Iowa Air Pollution Control Regulations	Chapter 567-23	Governs the release of fugitive dust in quantities creating a nuisance during site activities and emissions from a treatment system.
	Chapter 567-24	Applies to emissions from a permitted emission point. Could be applied to excess emissions of fugitive dust.
	Chapter 567-28	Ambient Air Quality Standards (Adopts 40 CFR 40).
	Chapter 567-30	Air Toxics
Iowa Water Pollution Control Regulations	Chapter 567-37	Registration of water well contractors.
	Chapter 567-38	Private water well construction permits.
	Chapter 567-40	Water supply definitions. Defines MCLs which Chapter 133 refers to.
	Chapter 567-49	These rules refer to nonpublic water wells, contains well construction standards, materials standards and abandonment guidelines.

APPENDIX A (CONTINUED)

POTENTIAL APPLICABLE RULES AND REGULATIONS

Standard, Requirement, Criteria or Limitation	Citation	Description
STATE (Continued)		
Iowa Water Pollution Control Regulations (Continued)	Chapters 567-60 to 64	Chapter 60 provides general definitions applicable in this title and rules of practice. Chapter 61 contains the water quality standards of the State including classification of surface waters. Chapter 62 contains the standards relevant to the discharge of pollutants to the waters of the state. Chapter 634 identifies monitoring, analytical and reporting requirements pertaining to specific permits for the operation of water disposal systems.
Iowa Environmental Quality Act	Chapter 455B	Defines the jurisdiction of the department, defines powers and duties of the commission and the director, civil or criminal proceedings to be undertaken by the State Attorney General.
Iowa Responsible Parties Cleanup Regulations	Chapter 133	These rules establish the procedures and criteria the Department will use to determine the parties responsible and cleanup actions necessary to meet the goals of the State pertaining to the protection of groundwater. These rules pertain to the cleanup of groundwater itself and soils and surface water where groundwater may be impacted.

APPENDIX B

OPERATION AND MAINTENANCE COST
ALTERNATIVE 1
NO ACTION/SITE MONITORING

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Annual Groundwater Sampling, Volatile Organic Compounds	Lump Sum	$ 4,500	-	$ 4,500
Maintain Existing Monitoring Well Network	Lump Sum	$ 1,000	-	$ 1,000
Engineering and Reporting	Lump Sum	$ 2,200	-	$ 2,200
Subtotal				$ 7,700
Contingency (20%)				$ 1,550
TOTAL ESTIMATED ANNUAL O&M COST				**$ 9,250**
ESTIMATED PRESENT VALUE COST[a] = $ 36,940				

[a] Assume 8% discount rate over a 5-year period.
- Indicates not applicable.

CAPITAL COST
ALTERNATIVE 1
NO ACTION/SITE MONITORING

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Monitoring Well[a]	Each	$ 3,100	2	$ 6,200
Subtotal				$ 6,200
Contingency (20%)				$ 1,250
TOTAL ESTIMATED CAPITAL COST				**$ 7,450**

[a] Assumes 2-inch PVC well, approximate depth = 20 feet. Includes oversight, installation, materials, and mobilization. Installation of wells within clean areas; disposal not required.

OPERATION AND MAINTENANCE COST
ALTERNATIVE 2
AIR SPARGING/SOIL VAPOR EXTRACTION

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Administrative Costs	Lump Sum	$ 5,000	-	$ 5,000
Maintenance of Remedial Equipment (blowers, wells)	Lump Sum	$ 50,000	-	$ 50,000
Power Requirements[a]				
Vapor Extraction Units (60 kW/Unit)	kWhr	$ 0.08	1,577,000	$126,000
Air Sparging Units (30 kW/Unit	kWhr	$ 0.08	788,000	$ 63,000
Discharge of Condensate[b]	Cubic Feet	$ .0142	211,000	$ 3,000
Treatment Costs	Lump Sum	$ 10,000	-	$ 10,000
Annual Groundwater Sampling, Volatile Organic Compounds	Lump Sum	$ 4,500	-	$ 4,500
Maintain Existing Monitoring Well Network	Lump Sum	$ 1,000	-	$ 1,000
Engineering and Reporting	Lump Sum	$ 4,500	-	$ 4,500
Subtotal				$267,000
Contingency (20%)				$ 53,500
TOTAL ESTIMATED ANNUAL O&M COST				**$320,500**
ESTIMATED PRESENT VALUE COST[c] = $ 1,280,000				

[a] Assumes 24 hours per day. Actual energy consumption may vary greatly.

[b] Assumes discharge of 3 gallons per minute, 24 hours per day.

[c] Assume 8% discount rate over a 5-year period.

\- Indicates not applicable.

CAPITAL COST
ALTERNATIVE 2
AIR SPARGING/SOIL VAPOR EXTRACTION

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Air Sparging Wells	Each	$ 2,500	31	$ 75,000
Soil Vapor Extraction Wells	Each	$ 2,500	41	$ 102,500
Contaminated Soil Disposal[a]	Each	$ 1,200	108	$ 129,600
Trenching and Piping	Lump Sum	$ 175,000	-	$ 175,000
Building (50 ft x 50 ft)	Lump Sum	$ 125,000	-	$ 125,000
Vapor Extraction Unit (60 kW/Unit)	Each	$ 50,000	3	$ 150,000
Sparging Unit (30 kW/Unit)	Each	$ 40,000	3	$ 120,000
Condensate Treatment System	Lump Sum	$ 50,000	-	$ 50,000
Controls, Monitoring Equipment, Electrical Appurtenances	Lump Sum	$ 100,000	-	$ 100,000
Other Miscellaneous Mechanicals (fittings, etc.)	Lump Sum	$ 200,000	-	$ 200,000
Design Engineering	Lump Sum	$ 50,000	-	$ 50,000
Construction Oversight	Lump Sum	$ 75,000	-	$ 75,000
Subtotal				$1,352,100
Contingency (20%)				$ 220,500
TOTAL ESTIMATED CAPITAL COST				**$1,572,600**

[a] Assumes three 55-gallon drums per well at approximately $1,200/drum; also assumes 1/2 of drums disposed since others will be in clean soil areas near outside of plume.

- Indicates not applicable.

OPERATION AND MAINTENANCE COST
ALTERNATIVE 3
GROUNDWATER EXTRACTION WELLS/DISCHARGE TO LOCAL POTW/
MONITOR GROUNDWATER IN AREA

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Administrative Costs	Lump Sum	$ 5,000	-	$ 5,000
Maintenance of Remedial Equipment (pumps, extraction wells)	Lump Sum	$ 5,000	-	$ 5,000
Power Requirements[a]				
Conveyance Pump (4 kW/Unit)	kWhr	$ 0.08	70,000	$ 5,600
Discharge Fee to POTW[b]	Cubic Feet	$ 0.0142	1,054,000	$ 15,000
Monthly Sampling for Discharge to POTW	Lump Sum	$ 600	12	$ 7,200
Annual Groundwater Sampling, Volatile Organic Compounds	Lump Sum	$ 4,500	-	$ 4,500
Maintain Existing Monitoring Well Network	Lump Sum	$ 1,000	-	$ 1,000
Engineering and Reporting	Lump Sum	$ 2,200	-	$ 2,200
Subtotal				$ 45,500
Contingency (20%)				$ 9,100
TOTAL ESTIMATED ANNUAL O&M COST				**$ 54,600**
ESTIMATED PRESENT ANNUALIZED COST[c] = $218,000				

[a] Assume 24 hours per day. Actual energy consumption may vary greatly.
[b] Assumes discharge equals 15 gallons per minute for 24 hours per day.
[c] Assume 8% discount rate over a 5-year period.
- Indicates not applicable.

CAPITAL COST
ALTERNATIVE 3
GROUNDWATER EXTRACTION WELLS/DISCHARGE TO LOCAL POTW/ MONITOR GROUNDWATER IN AREA

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Groundwater Extraction Well Construction[a]	Each	$ 4,500	19	$ 85,500
Light Duty Precast Hand Hole	Each	$ 1,000	19	$ 19,000
Pump Test	Lump Sum	$ 2,000	2	$ 4,000
Trenching	Linear Foot	$ 12	1,700	$ 20,400
PVC Piping (includes electrical conduit)	Linear Foot	$ 10	6,000	$ 60,000
Surge Tank (with overflow weir/sump)	Each	$ 5,000	1	$ 5,000
Centrifugal Pump	Each	$ 2,500	2	$ 5,000
Pressure Gauges	Each	$ 100	38	$ 3,800
Control Valves	Per Well	$ 500	19	$ 9,500
Flow Meter	Each	$ 1,000	4	$ 4,000
Electrical Panel and Controls (including labor)	Lump Sum	$ 50,000	-	$ 50,000
Pressure Test	Lump Sum	$ 5,000	-	$ 5,000
Other Miscellaneous Mechanicals (pipe, fittings, etc.)	Lump Sum	$ 50,000	-	$ 50,000
Design Engineering	Lump Sum	$ 20,000	-	$ 20,000
Construction Oversight	Lump Sum	$ 20,000	-	$ 20,000
Subtotal				$361,200
Contingency (20%)				$ 72,240
TOTAL ESTIMATED CAPITAL COST				**$433,440**

[a] Assume 8-inch diameter wells, stainless steel with PVC riser, 20 feet deep (includes well development and mobilization).

- Indicates not applicable.

OPERATION AND MAINTENANCE COST
ALTERNATIVE 4
GROUNDWATER INTERCEPTION TRENCH/DISCHARGE TO LOCAL POTW/
MONITOR GROUNDWATER IN AREA

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Administrative Costs	Lump Sum	$ 5,000	-	$ 5,000
Maintenance of Remedial Equipment	Lump Sum	$ 2,500	-	$ 2,500
Power Requirements[a]				
Sump Pump (1.5 kW)	kWhr	$ 0.08	13,000	$ 1,000
Discharge Fee to POTW[b]	Cubic Feet	$ 0.0142	703,000	$ 10,000
Monthly Sampling for Discharge to POTW	Lump Sum	$ 600	12	$ 7,200
Annual Groundwater Sampling, Volatile Organic Compounds	Lump Sum	$ 4,500	-	$ 4,500
Maintain Existing Monitoring Well Network	Lump Sum	$ 1,000	-	$ 1,000
Engineering and Reporting	Lump Sum	$ 2,200	-	$ 2,200
Subtotal				$ 33,400
Contingency (20%)				$ 6,700
TOTAL ESTIMATED ANNUAL O&M COST				**$ 40,100**
ESTIMATED PRESENT ANNUALIZED COST[c] = $160,100				

[a] Assume 24 hours per day. Actual energy consumption may vary greatly.
[b] Assumes discharge equals 10 gallons per minute for 24 hours per day.
[c] Assume 8% discount rate over a 5-year period.
- Indicates not applicable.

CAPITAL COST
ALTERNATIVE 4
GROUNDWATER INTERCEPTION TRENCH/DISCHARGE TO LOCAL POTW/ MONITOR GROUNDWATER IN AREA

Item Description	Unit	Unit Cost	Estimated Quantity	Projected Cost
Piezometers for Hydraulic Control	Each	$ 3,100	2	$ 6,200
Site Survey	Lump Sum	$ 2,000	-	$ 2,000
Site Prep (Mobilization, Site Grading, etc.)	Lump Sum	$ 51,000	-	$ 51,000
Trench Construction (includes sump, pump, etc.)	Lump Sum	$108,000	-	$108,000
Conveyance Piping	Lump Sum	$ 10,000	-	$ 10,000
Discharge Piping	Lump Sum	$ 4,800	-	$ 4,800
Site Restoration	Lump Sum	$ 6,300	-	$ 6,300
Surge Tank (with overflow weir/sump)	Each	$ 3,000	1	$ 3,000
Electrical Panel and Controls for POTW	Lump Sum	$ 10,000	-	$ 10,000
Design Engineering	Lump Sum	$ 23,000	-	$ 23,000
Construction Oversight	Lump Sum	$ 6,000	-	$ 6,000
Subtotal				$230,300
Contingency (20%)				$ 46,100
TOTAL ESTIMATED CAPITAL COST				**$276,400**

- Indicates not applicable.